Cambridge University Press
LONDON: BENTLEY HOUSE

CHICAGO
The University of Chicago Press
(Agents for the United States)

BOMBAY · CALCUTTA · MADRAS
Macmillan

The British Mycological Society

(*Recognosce notum, ignotum inspice*)

TRANSACTIONS

Volume XXVI

Edited by

B. BARNES and H. WORMALD

CAMBRIDGE
AT THE UNIVERSITY PRESS
1943

PRINTED IN GREAT BRITAIN

Vol. XXVI, Parts I & II 87398 April, 1943

SPHACELOMA ON WILLOW IN NEW ZEALAND

By ANNA E. JENKINS, *U.S. Department of Agriculture, Washington, D.C., U.S.A., and* LEON GRODSINSKY, *Ministerio de Agricultura de la Nacion, Buenos Aires, Argentina*

(With 1 Text-figure)

A special study of several destructive fungous-diseases of crack willow (*Salix fragilis* L.) and weeping willow (*S. babylonica* L.) growing in the Nelson district of New Zealand was made by Murray (1926). One of these maladies was reported to be the 'commonest disease of the crack-willows in this district' and also to affect weeping willows, although less frequently. The pathogen was referred to *Gloeosporium Capreae* Allesch., a species previously described on goat willow (*Salix Caprea* L.) from Germany. Murray pointed out, however, that her diagnosis of the fungus from New Zealand was not fully in agreement with the description of *Gloeosporium Capreae*. The present account is concerned with a new taxonomic interpretation of the fungus causing the willow disease discovered by Murray in New Zealand, here termed 'Gray Scab of Willow'.

Her description of this fungus follows:

> The fungus occurs only upon the leaves, forming upon the upper surface small round or irregular somewhat raised spots, greyish-white with a narrow dark-brown margin, varying from 0·5 mm. to 2 mm. in diameter, very often confluent and forming large irregular patches often up to 1·5 cm. long and exceptionally to 3·5 cm.; sometimes, especially when large and near the margin or tip of the leaf, a large part of the diseased area may drop away from the leaf; there is a tendency for the blotches to follow the veins of the leaf, so that long narrow patches may frequently be found along the midrib and larger veins (Plate II, fig. 3).* The spots are covered with minute black dots where the acervuli break through the cuticle. The under-surface of the leaf becomes discoloured with dark-brown areas corresponding to the spots above, but the acervuli are borne principally upon the upper surface.
>
> The acervuli are crowded, brown, small, 80–120 mm. in diameter, often confluent, in which case they are larger, erumpent, lifting up and breaking through the cuticle; conidiophores light-brown, 15–20 × 1–2 mm., bearing small oblong to oval, hyaline, one-celled conidia, 5–12 × 3–6 mm., often 2-guttulate (text-fig. 4).*

Miss Murray's illustrations represent an infected leaf of crack willow, showing many lesions, and a line drawing of an acervulus, the latter here reproduced (Fig. 1).

The fungus thus described by Murray is a typical species of *Sphaceloma* de Bary emend. Jenkins & Bitancourt (1941). Her account of this minute pathogenic organism appears to constitute the first record of any species of this genus on willow. The light brown conidiophores and the spore characters which she pointed out to be unlike those of Allescher's *Gloeosporium* on goat willow are characteristic of species of *Sphaceloma*. Murray's fungus appears to be distinct from the species described by Allescher.

* Not reproduced here.

Unfortunately, no material of this rarely reported European fungus is at hand. In Nannfeldt's (1931) tabulation of species of *Gloeosporium* on *Salix*, *Gloeosporium Capreae*, which, however, is accorded no special discussion, is among the few species retained in that genus. The omission of *G. subcuticulare* Caballero (1929) from the tabulation is doubtless owing to the nearly synchronous publication of the two articles concerned. In some respects the diagnosis of Caballero's species, described on crack willow from Spain, agrees more closely with the *Sphaceloma* from New Zealand than does *Gloeosporium Capreae*. There is no similarity between the two species, however, as was proved by a microscopic examination of authentic material of *G. subcuticulare*, contributed by Caballero. Judging from Miss Murray's description, the *Sphaceloma* on willow bears a certain resemblance to *S. Populi* (Sacc.) Jenkins (1933, 694), which is pathogenic on *Populus*, the other genus of the willow family. Nevertheless, before formulating any statement concerning the closer relationships of these two fungi, they should be critically compared, a problem beyond the scope of this paper.

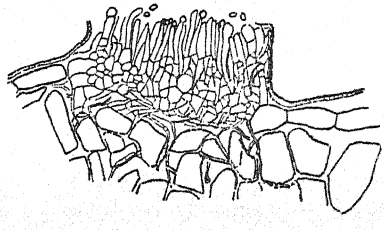


Fig. 1. *Sphaceloma Murrayae* on crack willow from New Zealand. After Murray. × 330.

As no fungus seems to have been described on *Salix* co-specific with the *Sphaceloma* discovered on *Salix* in New Zealand by Murray, it seems advisable to treat her fungus as a new species. It therefore is named in her honour, and a diagnosis in Latin based on her description in English follows:

Sphaceloma Murrayae sp.n. (Fig. 1)

Maculae epiphyllae parvae vel irregulares, paulo elevatae, griseo-albae margine angusto nigro-brunneo, hypophyllae nigro-brunneae, 0·5–2 mm. in diam., saepe confluentes et areas irregulares usque 1·5 cm., rare 3·5 cm. longas formantes, interdum praecipue magnae et prope marginem vel apicem folii locatae desciscentes, frequenter nervisequentes longae et angustae; acervuli abundantes, nigro-punctiformes, conferti, brunnei, parvi, 80–120μ in diam., saepe confluentes majoresque, cuticulam levantes et rumpentes; conidiophora pallide brunnea, 15–20μ longa, 1–2μ lata; conidia parva, oblonga vel ovoidea, hyalina, unicellularia, 5–12μ longa, 3–6μ lata, saepe 2-guttulata.

Hab. in foliis *Salicis fragilis* et rarius *S. babylonicae* (Salicaceae), prope Nelson, Nov. Zeland.

Icones: Murray, J. B., Pl. II, fig. 3 et Text-fig. 4. *Trans. Proc. N.Z. Inst.* LVI, 64–65, 1926, as *Gloeosporium Capreae* Allesch.

Sphaceloma Murrayae has also been found on *Salix viminalis* L., Delta del Paraná and Latvia, and on *S. fragilis*, United States. Grodsinsky, L. and Jenkins, A. E. *In* Rev. Argentine de Agron. (Unpublished.)

The work reported in this paper was done mainly in 1940, when the junior author was on leave of absence in the United States.

REFERENCES

CABALLERO, A. (1929). Algunas novedades botánicas de la Real Casa de Campo y de El Pardo. *Mem. Soc. esp. Hist. nat.* XV, 309–14.

JENKINS, A. E. (1933). *Elsinoe* on apple and pear. *J. agric. Res.* XLIV, 689–700.

JENKINS, A. E. & BITANCOURT, A. A. (1941). Revised descriptions of the genera *Elsinoe* and *Sphaceloma*. *Mycologia*, XXIII, 338–40.

MURRAY, B. J. (1926). Three fungus diseases of *Salix* in New Zealand and some saprophytic fungi on the same hosts. *Trans. Proc. N.Z. Inst.* LVI, 58–70.

NANNFELDT, J. A. (1931). Contributions to the mycoflora of Sweden. 2. *Excipula sphaeroides* Fr., some other discomycetes on *Salix*-leaves and their conidial stages. *Svensk bot. Tidskr.* XXV, 1–31.

(*Accepted for publication* 15 *April* 1942)

ON THE GENERIC NAMES *PSEUDOMONAS, XANTHOMONAS* AND *BACTERIUM* FOR CERTAIN BACTERIAL PLANT PATHOGENS

By W. J. DOWSON, *Botany School, Cambridge*

It has long been recognized that the majority of bacterial plant pathogens are very similar to certain commonly occurring saprophytic species with which they may have evolved from a common ancestral type. Thus the green fluorescent plant pathogens may be regarded as parasitic forms of the saprophytes *Pseudomonas fluorescens* Migula and *P. putida* Migula, the former of which possesses proteolytic enzymes absent in the latter, i.e. one liquefying gelatine, the other unable to do so. Soft-rotting plant pathogens are closely akin to the colon bacillus both in morphological characters and in biochemical activities. All these bacteria were classified by Lehmann and Neumann (1927) in their genus *Bacterium*, which comprised all the Gram-negative non-sporing, rod-shaped forms irrespective of the presence or absence of flagella. They divided the genus into subgenera according to the arrangement of flagella when present, such as *Bacterium* proper, containing bacteria with peritrichous flagella, and *Pseudomonas*, with polar flagella. The latter name was taken from Migula's system (1900) and embraced the same organisms as Migula had in mind, namely, green fluorescent forms possessing a tuft of polar flagella and yellow species provided with a single polar flagellum. Many bacteriologists consider this to be the natural position for the plant pathogens as it indicates that they are regarded as but distinct species of the two genera *Bacterium* and *Pseudomonas*.

In Bergey's system (1939) the same two groups are recognized, but under different names and in different positions in the classification. The pathogens with peritrichous flagella are not placed in the same genus as the colon bacillus (called by Bergey *Escherichia*) but in a separate genus, *Erwinia* Winslow *et al.*, though both are included with other genera in a family Enterobacteriaceae. The other group of plant pathogens, corresponding to *Pseudomonas* Migula, is placed in a genus *Phytomonas* Bergey, which is grouped next to *Pseudomonas* (also borrowed from Migula) in the family Pseudomonadaceae. These two genera, *Erwinia* and *Phytomonas*, were created solely for bacteria pathogenic to plants, irrespective of all other characters.

I recently (1939, 1941) discussed the characters of a number of plant pathogens, compared them with the colon bacillus and with *Pseudomonas fluorescens*, and gave reasons for rejecting the generic names *Erwinia* and *Phytomonas*. The generic name *Bacterium* was retained but was redefined. *Pseudomonas* Migula was split into two genera. *Pseudomonas* Migula em. Dowson was used for the green fluorescent bacteria with a tuft of polar flagella, e.g. *P. syringae*, and *Xanthomonas* Dowson for the yellow forms with a single polar flagellum such as *Pseudomonas campestris*. A definition of the

proposed new genus *Xanthomonas* was provided and *Bacterium hyacinthi* Wakker (1884) was selected as type species. This proposal is in accordance with the International Rules of Botanical Nomenclature and has received approval both in Britain and in America. Some authorities, however, while accepting *Xanthomonas* and *Pseudomonas* (Migula) emend. still prefer *Erwinia* to *Bacterium* for the peritrichous plant pathogens, i.e. *Erwinia carotovora* rather than *Bacterium carotovorum*. The genus *Erwinia* should be discarded for the following reasons. It was created on one character alone, that of pathogenicity to plants (Winslow, C.-E. A., Broadhurst, J., Buchanan, R. E., Krumweide, C., Rogers, L. A. & Smith, G. H., 1917). Bergey evidently regarded this as valid, for he stated: 'Tribe II Erwineae Winslow *et al.* (1920). Plant pathogens. Invade the tissues of plants and produce local lesions; some killing the host plants. Usually motile with peritrichous flagella. Ferment dextrose and lactose with formation of acid, or acid and visible gas. Usually attack pectin. There is a single genus *Erwinia* (Winslow *et al.*).'

The few biochemical activities recorded in this definition are equally applicable to other bacteria, including the colon bacillus of the genus *Escherichia*, which Bergey defined as: '*Escherichia* Castellani and Chalmers. Non-spore forming, Gram-negative short rods fermenting dextrose and lactose with acid and gas. Commonly occurring in the intestinal canal of animals. Widely distributed in nature. M.R. test positive. Voges-Proskauer reaction negative. Carbon dioxide and hydrogen produced in approximately equal volumes from dextrose.' The only real difference between the two definitions is that of habitat, plants in one, animals in the other. *Erwinia carotovora* (Jones) Holland, *E. aroideae* (Townsend) Holland, *E. phytophthora* (Appel) Bergey and *E. tracheiphila* (Erw. Smith) Holland, however, are found in the intestinal canal of certain insects (Johnson, 1930; Gilbert, 1928) as well as in plants, and according to Bergey the first two are widely distributed in nature.

The separation of plant pathogens from the similar colon-typhoid group was not accepted even in America without protest, for Breed, Conn & Baker (1918) wrote: 'still more questionable is the genus *Erwinia*.... It is very doubtful, indeed, whether peritrichic plant parasites are sufficiently distinct from saprophytes to be put in a genus by themselves.' Moreover, Burkholder (1930) stated that: 'this tribe (i.e. Erwineae) is based entirely upon the ability of its members to cause disease in plants, and all other characters of the bacteria are disregarded. The reason for the separation of the plant pathogens was not discussed and it seems evident that the close relationship of the genus *Erwinia* to the *coli* group, and certain members of the genus *Phytomonas* to the fluorescent group was overlooked or not known.' Commenting on the fifth edition of Bergey, Burkholder (1939) observed: 'it is no longer considered that the plant pathogens form a distinct group of their own, and the concept that plant pathogenicity is a generic character is being weakened.' In Europe bacteriologists also took exception to the separation. Topley and Wilson (1936) stated: 'we have retained the genus *Erwinia*.... It seems doubtful whether the plant pathogens should be segregated in this way....'

In addition to separating the components of the colon-typhoid group on habitat and pathogenicity small differences in biochemical activity were also regarded as generic characters by the compilers of Bergey's system. For instance, Bergey's tribe V of the Enterobacteriaceae is called Salmonellae and contains two 'genera', *Salmonella* Lignières and *Eberthella* Buchanan, which are distinguished by the fact that the latter fails to form gas in fermenting a number of carbohydrates. Other biochemical activities, such as the reduction of nitrates to nitrites, which all the members of the Enterobacteriaceae are said to do (Bergey *et al.* 1939, p. 388), do not appear to matter, for *Erwinia* includes four species that do not exhibit this character. Two of them are the plant pathogens *E. amylovora* and *E. tracheiphila*. In fact, apart from such small differences the four 'genera' *Escherichia*, *Erwinia*, *Eberthella* and *Salmonella* are identical.

The characters upon which Bergey relied to distinguish genera were therefore differences in habitat, or in pathogenicity, or in chemical activity, which many bacteriologists regard as useful only in differentiating species. These biochemical differences are not always sufficient even to distinguish species, for, as Lacey (1939) has shown, different isolates of the fasciation and leafy gall bacterium (*Corynebacterium fascians* (Tilford) Dowson) may or may not produce acid from lactose. Kluyver and van Niel (1936) used the generic name *Bacterium* for most of the colon-like bacteria, and in referring to their definition of the genus they stated (p. 402 footnote 2): 'it should be well understood that in this genus are included the genera *Proteus*, *Salmonella*, *Eberthella* and *Shigella* which nowadays are frequently used. Although specialists dealing with this group may feel the need for further subdivision, yet it is unacceptable to us to differentiate genera on such trifling characters as are used in the current systems. Two organisms which ferment glucose in essentially the same way should not, in our opinion, be placed in separate genera, because one of them ferments (i.e. hydrolyses) also lactose. Nor should this be done because one of them splits formic acid into carbon dioxide and hydrogen, whereas the other does not (i.e. acid but no gas produced!).' Topley and Wilson (1936) also adopted the generic name *Bacterium* with certain reservations and amendments for those bacteria comprising what is generally recognized as the colon-typhoid-dysentery group, apart from which it is 'in accordance with the reports of the American Committee' (Winslow *et al.* 1917 and 1920). For convenience they divided the genus into five groups: Coli-aerogenes, Friedländer, paracolon, dysentery and *Salmonella*, but they pointed out the tendency of specialists concentrating on any one group to subdivide it according to some definite character such as antigenic structure, and to consider that particular group as a genus regardless of closely similar groups. Topley and Wilson also drew attention to the different methods adopted by specialists for denoting the 'species' into which a group is divided and compared *Salmonella* with *Streptococcus* (*Pneumococcus*). The former has been divided into numerous 'species' according to differences in antigenic structure and place of isolation, e.g. *Salmonella newport* var. *Kottbus* or *S. enteritidis* var. *Chaco*, whereas the latter has been separated into numbered antigenic types, e.g. *Streptococcus pneumoniae* Type VIII.

Topley and Wilson concluded (1936, p. 549): 'while in full agreement with the Salmonella sub-committee in regard to the fundamental importance of antigenic structure and the necessity for labelling each new type it appears to us that the accordance of specific rank to each of the ultimate types that can be differentiated by these means is a questionable procedure. It will clearly increase the present chaos of bacteriological nomenclature if we attach one meaning to the term "species" in the genus *Bacterium* and another meaning in the genus *Streptococcus*...we feel unable to adopt the generic name *Salmonella* which the sub-committee upholds.'

The same differences in biochemical activities and in antigenic structure are thus held by one school of bacteriologists to be *specific* and by another to be *generic*, and are instances of the fundamentally different and sometimes incompatible aims in classifying organisms. The aim of one school is to group related forms in such a way as to express the probable course of evolution, which means that attention is chiefly paid to similarities between forms. The aim of another school is to differentiate species and to arrange all organisms in artificial keys by reference to which any unknown species may be readily identified. They pay more attention to differences than to similarities. Bergey's *Manual* is a catalogue of species and a work of reference with artificial keys for identification in which differences are more accentuated than similarities. Kluyver and van Niel's system, on the other hand, is an attempt to classify bacteria according to their supposed lines of morphological and physiological evolution, and it involves the use of katabolic products as aids or indications in differentiating species. The 'genera' of Bergey's family Enterobacteriaceae become the 'species' of the genus *Bacterium* as defined by Topley and Wilson and by Kluyver and van Niel.

The terms genera and species as applied to bacteria are hard to define. To quote Topley and Wilson (1936, p. 217) they 'seem to us to defy definition, except as designations for two convenient groupings of which the genus is the larger including group, and the species the smaller included group. For this reason and because of the absence of any form of international agreement, we doubt the usefulness, at the present time, of naming orders, families, subfamilies and tribes. Nor do we feel that the time is ripe for the creation of a large number of genera, or for the erection of an inelastic system into which all known varieties of bacteria are to be forced, each with its appropriate label.' In classifying the colon-like bacteria it seems to me that this is the best principle to follow, and in adopting *Bacterium* as a generic name for this group of bacteria more accurate information can be conveyed in a binomial than by dividing the group into so-called genera, the names of which convey no sense of relation between the various subgroups. The names *Bacterium salicis*, *Bact. coli*, *Bact. typhosum*, and *Bact. enteritidis* undoubtedly provide more information about these four organisms than do the names *Erwinia salicis*, *Escherichia coli*, *Eberthella typhi* and *Salmonella enteritidis*. The specific epithets tell us that the organisms are connected with willows, the large intestine, typhoid fever and enteric fever respectively, but whereas in the first series the use of the

single generic name implies that all four bacteria are closely related, in the second series no such relation is indicated and the generic names merely commemorate four distinguished bacteriologists. For these reasons I consider that the generic names *Erwinia*, *Escherichia*, *Eberthella* and *Salmonella* should be rejected and replaced by *Bacterium*.

The chief objection to the generic name *Bacterium* is stated by Breed and Conn (1936) to be that 'the type species *Bacterium triloculare* Ehrenberg 1828 (monotypy) is unrecognizable. Because this species is unrecognizable subsequent authors have felt free to redefine the genus. As none of these new definitions have won universal approval, it is necessary to state how the term is being used each time it is used or confusion results. This situation pointedly illustrates the need for the rule that generic terms not associated with a recognizable type are invalid....' But there is nothing in the International Rules of Botanical Nomenclature to prevent the redefining of a generic name, and this has in fact been done more than once, e.g. with *Bacillus*. Furthermore, Breed and Conn (1936) omit all mention of the very significant fact that 'subsequent authors who felt free to redefine the genus' chose the same organism for their type species, viz. the colon bacillus, the original name of which was *Bacterium coli commune* (Escherich, 1885). The generic name *Bacterium* as used by these subsequent authors has in fact a very recognizable type species, and the one combination to receive more approval than any other for this well-known bacterium is *Bact. coli*. Moreover, under the type species concept 'the genus is defined primarily by means of a type species rather than by means of a statement of the common distinguishing characters of the species in the genus' (Breed, 1928).

The generic name *Bacterium* is used at the present time for the whole of the colon-typhoid-dysentery group by medical bacteriologists such as Topley and Wilson (1936), and for a part of the group by Jordan and Burrows (1941) who excluded the typhoid-paratyphoid bacteria for which they recognized the generic name *Salmonella*. Kluyver and van Niel (1936) advocated *Bacterium* for the whole group except *Bact. aerogenes* which they placed under Beijerinck's genus *Aerobacter*. In plant pathology Brooks (1928) and Burgwitz (1936) adopted the definition of Lehmann and Neumann (1927) and used *Bacterium* for all bacterial plant pathogens, while Stapp (1937) employed this term for one peritrichous species only, and substituted *Bacterium* for *Bacillus* for the potato blackleg pathogen. Most authorities appear to agree that the scope of *Bacterium* as defined by Lehmann and Neumann is too comprehensive, and the consensus of opinion of the medical authorities who use this generic name seems to be that *Bacterium* should denote either the whole or at least a part of the colon-typhoid group. To this plant pathologists would add the peritrichous plant pathogens.

In conclusion, I would make the following recommendations based on the arguments brought forward above:

1. That the generic names *Erwinia*, *Escherichia*, *Eberthella*, *Salmonella* and others of Bergey's Enterobacteriaceae such as *Shigella*, *Klebsiella*, and *Aerobacter* be discarded.

2. That *Bacterium* Ehrenberg, 1828 be designated as a *nomen conservandum*.

3. That the type species of *Bacterium* should be designated as *Bacterium coli* Escherich, 1885.

4. That the genus *Bacterium* should be so defined as to include not only those species universally regarded as constituting the colon-typhoid-dysentery group but also the peritrichous plant pathogens.*

In conclusion I would like to express my thanks for helpful criticism and comments from Mr W. C. Moore and Dr S. P. Wiltshire, and particularly to Mr E. W. Mason for his advice regarding the authorities for the names in the list of pathogens.

The following is a list of the Gram-negative bacterial plant pathogens to be included in the three genera *Pseudomonas* Migula em. Dowson 1939, *Xanthomonas* Dowson, 1939 and *Bacterium* Ehrenberg em. Dowson 1939. Following most of the names are two synonyms, the first being the original name given to the organism together with its author and date, the second is that accepted by Bergey (1939). Where only one synonym appears it is the name advocated by Bergey.

Pseudomonas Migula emend. Dowson, 1939

P. aleuritidis (McCulloch & Demaree) Stapp; *Bacterium aleuritidis* McCulloch & Demaree, 1932; *Phytomonas aleuritidis* (McCulloch & Demaree) Magrou.

P. andropogonis (Smith) Stapp; *Bacterium andropogonis* E. F. Smith, 1911; *Phytomonas andropogonis* (Smith) Bergey.

P. angulata (Frome & Murray) Stapp; *Bacterium angulatum* Frome & Murray, 1919; *Phytomonas angulata* (Frome & Murray) Bergey.

P. apii Jagger, 1921; *P. jaggeri* Stapp; *Phytomonas jaggeri* (Stapp) Magrou.

P. aptata (Brown & Jamieson) Stapp; *Bacterium aptatum* Brown & Jamieson, 1913; *Phytomonas aptata* (Brown & Jamieson) Bergey.

P. atrofasciens (McCulloch) Stapp; *Bacterium atrofasciens* McCulloch, 1920; *Phytomonas atrofasciens* (McCulloch) Bergey.

P. barkeri (Berridge) Clara; *Bacillus barkeri* Berridge, 1924; *Phytomonas barkeri* (Berridge) Bergey.

P. berberidis (Thornberry & Anderson) Stapp; *Phytomonas berberidis* Thornberry & Anderson, 1935.

P. betae (Wieringa) n.comb.; *Phytomonas betae* Wieringa, 1927; *Phytomonas* wieringae (Elliott) Bergey.

P. bowlesii (Lewis & Watson) n.comb.; *Phytomonas bowlesii* Lewis & Watson, 1927.

P. calendulae (Takimoto) n.comb.; *Bacterium calendulae* Takimoto, 1936; *Phytomonas calendulae* (Takimoto) Bergey.

P. cannae (Bryan) Stapp; *Bacterium cannae* Bryan, 1921; *Phytomonas cannae* (Bryan) Bergey.

* With regard to recommendation 4, bacteriologists have accepted the principle of delimiting genera by International action (St John-Brooks & Breed, 1937), but no such provision is made in the International Rules of Botanical Nomenclature.

P. cerasi Griffin, 1911; *Phytomonas cerasi* (Griffin) Bergey (=*Bacterium trifoliorum* Jones *et al.*=*Bacterium holci* Kendrick. (See Clara, F. M. (1934), *Mem. Cornell Univ. Agric. Exp. Sta.* (159.))

P. coronafasciens (Elliott) Stapp; *Bacterium coronafasciens* Elliott, 1920; *Phytomonas coronafasciens* (Elliott) Bergey.

P. cumini (Kovacevski) n.comb.; *Phytomonas cumini* Kovacevski, 1936.

P. delphinii (Smith) Stapp; *Bacillus delphinii* E. F. Smith, 1904; *Phytomonas delphinii* (Smith) Bergey.

P. eriobotryae (Takimoto) n.comb.; *Bacterium eriobotryae* Takimoto, 1931; *Phytomonas eriobotryae* (Takimoto) Bergey.

P. erodii Lewis, 1914; *Phytomonas erodii* (Lewis) Bergey.

P. gardeniae (Burkholder) n.comb.; *Phytomonas gardeniae* Burkholder, 1941.

P. gladioli Severini, 1913; *Phytomonas gladioli* (Severini) Magrou.

P. glycinea Coerper, 1919; *Phytomonas glycinea* (Coerper) Burkholder (=*Pseudomonas sojae* (Wolf) Stapp).

P. hibisci (Nataka & Takimoto) Stapp; *Bacterium hibisci* Nataka & Takimoto, 1923; *Phytomonas hibisci* (Nataka & Takimoto) Bergey.

P. lacrymans (Smith & Bryan) Ferraris; *Bacterium lacrymans* Smith & Bryan, 1915; *Phytomonas lacrymans* (Smith & Bryan) Bergey.

P. maculicola (McCulloch) Stevens; *Bacterium maculicola* McCulloch, 1911; *Phytomonas maculicola* (McCulloch) Bergey.

P. marginalis (Brown) Stapp; *Bacterium marginale* Brown, 1918; *Phytomonas marginalis* (Brown) Bergey.

P. martyniae (Elliott) Stapp; *Bacterium martyniae* Elliott, 1924; *Phytomonas martyniae* (Elliott) Bergey.

P. matthiolae (Briosi & Paverino) n.comb.; *Bacterium matthiolae* Briosi & Paverino, 1912; *Phytomonas matthiolae* (Briosi & Paverino) Bergey.

P. medicaginis Sackett, 1910; *Phytomonas medicaginis* (Sackett) Bergey.

P. medicaginis var. *phaseolicola* (Burkholder) Dowson; *Phytomonas medicaginis* var. *phaseolicola* Burkholder, 1926. (I suggest *P. phaseolicola* n.comb. for this *Bacterium*.)

P. mellea (Johnson) Stapp; *Bacterium melleum* Johnson, 1923; *Phytomonas mellea* (Johnson) Bergey.

P. mori (Boyer & Lambert) Stevens; *Bacterium mori* Boyer & Lambert, 1893; *Phytomonas mori* (Boyer & Lambert) Bergey.

P. mors-prunorum Wormald, 1931; *Phytomonas mors-prunorum* (Wormald) Wormald.

P. nectarophila (Doidge) Dowson; *Bacterium nectarophilum* Doidge, 1917; *Phytomonas nectarophila* (Doidge) Bergey.

P. panacis (Takimoto) n.comb.; *Bacterium panaxi* Takimoto, 1922; *Phytomonas panaxi* (Takimoto) Magrou.

P. panici (Elliott) Stapp; *Bacterium panici* Elliott, 1923; *Phytomonas panici* (Elliott) Bergey.

P. papulans Rose, 1917; *Phytomonas papulans* (Rose) Bergey.

P. pisi Sackett, 1916; *Phytomonas pisi* (Sackett) Bergey.

P. primulae (Ark & Gardner) n.comb.; *Phytomonas primulae* Ark & Gardner, 1936.

P. prunicola Wormald, 1930; *Phytomonas prunicola* Wormald, 1930 (?=*P. cerasi*).

P. pseudozoogloeae (Honing) Stapp; *Bacterium pseudozoogloeae* Honing, 1914; *Phytomonas pseudozoogloeae* (Honing) Bergey.
P. punctulans (Bryan) n.comb.; *Bacterium tomato* Okabe, 1933; *Phytomonas tomato* (Okabe) Magrou. (See Bryan, 1933.)
P. rimaefasciens Koning, 1938; *Phytomonas rimaefasciens* (Koning) Bergey.
P. saliciperda Lindeijer, 1932; *Phytomonas saliciperda* (Lindeijer) Bergey.
P. savastanoi (Smith) Stevens; *Bacterium savastanoi* Smith, 1908; *Phytomonas savastanoi* (Smith) Bergey.
P. savastanoi var. *fraxini* (Brown) Dowson; *Bacterium savastanoi* var. *fraxini* Brown, 1932; *Phytomonas savastanoi* var. *fraxini* (Brown) Magrou. (I suggest *Pseudomonas fraxini* n.comb. for this organism.)
P. striafascians (Elliott) Stapp; *Bacterium striafascians* Elliott, 1927; *Phytomonas striafascians* (Elliott) Bergey.
P. syringae van Hall, 1902; *Phytomonas syringae* (Van Hall) Bergey. (=*Bacterium citriputeale* C. O. Smith=*Bacterium vignae* Gardner & Kendrick. See Clara, F. M. (1934), *Mem. Cornell Univ. Agric. Exp. Sta.* no. 159.)
P. tabaci (Wolf & Foster) Stapp; *Bacterium tabacum* Wolf & Foster, 1917; *Phytomonas tabaci* (Wolf & Foster) Bergey.
P. tolaasi Paine, 1919; *Phytomonas tolaasi* (Paine) Bergey.
P. utiformica Clara, 1932; *Phytomonas utiformica* Clara.
P. viburni (Thornberry & Anderson) Stapp; *Phytomonas viburni* Thornberry & Anderson, 1931.
P. viridiflava (Burkholder) Dowson; *Phytomonas viridiflava* Burkholder, 1930.
P. viridilivida (Brown) Stapp; *Bacterium viridilividum* Brown, 1915; *Phytomonas viridilivida* (Brown) Bergey.
P. woodsii (Smith) Stapp; *Bacterium woodsii* Smith 1911; *Phytomonas woodsii* (Smith) Bergey.

Xanthomonas Dowson, 1939

X. albilineans (Ashby) n.comb.; *Bacterium albilineans* Ashby, 1929; *Phytomonas albilineans* (Ashby) Magrou.
X. alfalfae (Riker, Jones & Davis) n.comb.; *Phytomonas alfalfae* Riker, Jones & Davis, 1933.
X. antirrhini (Takimoto) n.comb.; *Pseudomonas antirrhini* Takimoto, 1920; *Phytomonas antirrhini* (Takimoto) Magrou.
X. barbarea Burkholder, 1941.
X. begoniae (Takimoto) Dowson; *Bacterium begoniae* Takimoto, 1934; *Phytomonas begoniae* (Takimoto) Bergey.
X. campestris (Pammel) Dowson; *Bacillus campestris* Pammel, 1895; *Phytomonas campestris* (Pammel) Bergey.
X. carotae (Kendrick) Dowson; *Phytomonas carotae* Kendrick, 1934.
X. celebensis (Gaumann) n.comb.; *Pseudomonas celebensis* Gaumann, 1923; *Phytomonas celebensis* (Gaumann) Magrou.
X. citri (Hasse) Dowson; *Pseudomonas citri* Haase, 1915; *Phytomonas citri* (Haase) Bergey.
X. corylina (Miller *et al.*) n.comb.; *Phytomonas corylina* Miller *et al.* 1940.

X. cucurbitae (Bryan) Dowson; *Bacterium cucurbitae* Bryan, 1926; *Phytomonas cucurbitae* (Bryan) Bergey.

X. dieffenbachiae (McCulloch & Pirone) n.comb.; *Bacterium dieffenbachiae* McCulloch & Pirone, 1939; *Phytomonas dieffenbachiae* McCulloch & Pirone.

X. hederae (Arnaud) Dowson; *Bacterium hederae* Arnaud, 1920; *Phytomonas hederae* (Arnaud) Burkholder & Guterman.

X. holcicola (Elliott) n.comb.; *Bacterium holcicola* Elliott, 1930; *Phytomonas holcicola* (Elliott) Bergey.

X. hyacinthi (Wakker) Dowson; *Bacterium hyacinthi* Wakker, 1883; *Phytomonas hyacinthi* (Wakker) Bergey.

X. geranii (Burkholder) Dowson; *Phytomonas geranii* Burkholder, 1937.

X. gummisudans (McCulloch) n.comb.; *Bacterium gummisudans* McCulloch, 1924; *Phytomonas gummisudans* (McCulloch) Bergey.

X. itoana (Tochinai) n.comb.; *Pseudomonas itoana* Tochinai, 1932; *Phytomonas itoana* (Tochinai) Magrou.

X. juglandis (Pierce) Dowson; *Pseudomonas juglandis* Pierce, 1901; *Phytomonas juglandis* (Pierce) Bergey.

X. lactucae (Yamamoto) n.comb.; *Bacterium lactucae* Yamamoto, 1934; *Phytomonas lactucae* (Yamamoto) Bergey.

X. malvacearum (Smith) Dowson; *Pseudomonas malvacearum* Smith, 1901; *Phytomonas malvacearum* (Smith) Bergey.

X. nakatae (Okabe) n.comb.; *Bacterium nakatae* Okabe, 1933; *Phytomonas nakatae* (Okabe) Bergey.

X. nigromaculans (Takimoto) n.comb.; *Bacterium nigromaculans* Takimoto, 1927; *Phytomonas nigromaculans* (Takimoto) Magrou.

X. oryzae (Uyeda & Ishiyama) n.comb.; *Pseudomonas oryzae* Uyeda & Ishiyama, 1926; *Phytomonas oryzae* (Uyeda & Ishiyama) Magrou.

X. papavericola (Bryan & McWhorter) Dowson; *Bacterium papavericola* Bryan & McWhorter, 1930; *Phytomonas papavericola* (Bryan & McWhorter) Bergey.

X. phaseoli (Smith) Dowson; *Bacterium phaseoli* Smith, 1905; *Phytomonas phaseoli* (Smith) Bergey.

X. phormicola (Takimoto) n.comb.; *Bacterium phormicola* Takimoto, 1933; *Phytomonas phormicola* (Takimoto) Bergey.

X. pruni (Smith) Dowson; *Pseudomonas pruni* Smith, 1903; *Phytomonas pruni* (Smith) Bergey.

X. ricinicola (Elliott) Dowson; *Bacterium ricini* Yoshi & Takimoto, 1928; *Phytomonas ricinicola* (Elliott) Bergey.

X. rubrilineans (Lee *et al.*) n.comb.; *Phytomonas rubrilineans* Lee *et al.* 1925.

X. solanacearum (Smith) Dowson; *Bacillus solanacearum* Smith, 1896; *Phytomonas solanacearum* (Smith) Bergey.

X. tardicrescens (McCulloch) n.comb.; *Phytomonas tardicrescens* McCulloch, 1937.

X. translucens (Jones *et al.*) Dowson; *Bacterium translucens* Jones *et al.* 1917; *Phytomonas translucens* (Jones *et al.*) Bergey.

X. vasculorum (Cobb) Dowson; *Bacillus vasculorum* Cobb, 1893; *Phytomonas vasculorum* (Cobb) Bergey.

X. vesicatoria (Doidge) Dowson; *Bacterium vesicatorium* Doidge, 1920; *Phytomonas vesicatoria* (Doidge) Bergey.

X. vitians (Brown) n.comb.; *Bacterium vitians* Brown, 1918; *Phytomonas vitians* (Brown) Bergey.

Bacterium Ehrenberg, 1828 emend. Dowson, 1939

The generic name *Bacterium* has been used hitherto by various authors with different meanings; thus Chester (1901) used the term to denote sporing or non-sporing, non-motile, rod-shaped bacteria: Lehmann and Neumann (1927) defined *Bacterium* as non-sporing, motile or non-motile rod-shaped bacteria, and Elliott (1930) used the name for rod-shaped bacteria provided with polar flagella. I have restricted *Bacterium* to comprise Gram-negative, non-sporing, rod-shaped bacteria with peritrichous flagella and their non-motile variants (for a more comprehensive definition see Dowson, 1939).

B. amylovorum (Burrill) Chester; *Micrococcus amylovorus* Burrill, 1882; *Erwinia amylovora* (Burrill) Winslow *et al.*

B. ananas (Serrano) Burgwitz; *Bacillus ananas* Serrano, 1928; *Erwinia ananas* Serrano, 1928.

B. aroideae (Townsend) Stapp; *Bacillus aroideae* Townsend, 1901; *Erwinia aroideae* (Townsend) Holland.

B. carotovorum (Jones) K. B. Lehmann; *Bacillus carotovorus* Jones, 1901; *Erwinia carotovora* (Jones) Holland.

B. cassavae Hansford, 1936.

B. citrimaculans (Doidge) Burgwitz; *Bacillus citrimaculans* Doidge, 1917; *Erwinia citrimaculans* (Doidge) Magrou.

B. mangiferae (Doidge) Burgwitz; *Bacillus mangiferae* Doidge, 1915; *Erwinia mangiferae* (Doidge) Bergey.

B. marginatum McCulloch, 1921; *Phytomonas marginata* (McCulloch) Bergey.

B. phytophthorum (Appel) Burgwitz; *Bacillus phytophthorus* Appel, 1902; *Erwinia phytophthora* (Appel) Bergey.

B. pseudotsugae Hansen & R. E. Smith, 1937; *Phytomonas pseudotsugae* (Hansen & R. E. Smith) Bergey = *B. tumefaciens* Smith & Townsend.

B. rhaponticum Millard, 1924; *Phytomonas rhapontica* Millard, 1924.

B. rhizogenes Riker *et al.* 1930; *Phytomonas rhizogenes* Riker *et al.*

B. salicis Day, 1924; *Erwinia salicis* (Day) Bergey.

B. tracheiphilum (Smith) Burgwitz; *Bacillus tracheiphilus* Smith, 1895; *Erwinia tracheiphila* (Smith) Holland.

B. tumefaciens Smith & Townsend, 1907; *Phytomonas tumefaciens* (Smith & Townsend) Bergey.

REFERENCES

BERGEY *et al.* (1939). *Manual of Determinative Bacteriology*, 5th ed.

BREED, R. S. (1928). The present status of systematic bacteriology. *J. Bact.* XV, 145–63.

BREED, R. S. & CONN, J. H. (1936). The status of the generic term Bacterium Ehrenberg 1828. *J. Bact.* XXXI, 517–18.

BREED, R. S., CONN, J. H. & BAKER, J. C. (1918). Comments on the evolution and classification of bacteria. *J. Bact.* III, 445–59.

BROOKS, F. T. (1928). *Plant Diseases*, p. 37.
BRYAN, M. K. (1933). Bacterial speck of tomatoes. *Phytopathology*, XXIII, 897–904.
BURGWITZ, G. K. (1936). *Bacterial Diseases of Plants*. Leningrad. Cited in *Rev. appl. Myc.* XVI, 302.
BURKHOLDER, W. H. (1930). The genus *Phytomonas*. *Phytopathology*, XX, 1–23.
BURKHOLDER, W. H. (1939). The taxonomy and nomenclature of the phytopathogenic bacteria. *Phytopathology*, XXIX, 128–36.
CHESTER, F. D. (1901). *Manual of Determinative Bacteriology*.
DOWSON, W. J. (1939). On the systematic position and generic names of the Gram-negative bacterial plant pathogens. *Zentralbl. f. Bakt.* II Abt. C, 177–93.
DOWSON, W. J. (1941). Systematics of gram-negative bacterial plant pathogens. *Chron. Bot.* VI, 197–8.
ELLIOTT, C. (1930). *Manual of Bacterial Plant Pathogens*.
ESCHERICH, T. (1885). Die Darmbakterien des Neugeborenen und Säuglings. *Fortschr. Med.* III, 515, 547.
GILBERT, W. W. (1928). Control of cantaloupe diseases in Maryland. *Rept. Maryland Agr. Soc. and Maryland Farm Bureau Federation*, XII (1927), 401. Cited in Elliott's *Manual of Bacterial Plant Pathogens*, 1930, p. 84.
JOHNSON, D. E. (1930). The relation of the cabbage maggot and other insects to the spread and development of soft rot of Cruciferae. *Phytopathology*, XX, 857–72.
JORDAN, E. O. & BURROWS, W. (1941). *Textbook of Bacteriology*, 13th ed.
KLUYVER, A. J. & VAN NIEL, C. B. (1936). Prospects for a natural system of classification of bacteria. *Zentralbl. f. Bakt.* II Abt. XCIV, 369–403.
LACEY, M. S. (1939). Studies on a bacterium associated with leafy galls, fasciation and 'cauliflower' disease of various plants. Part III. Further isolations, inoculation experiments and cultural studies. *Ann. appl. Biol.* XXVI, 262–78.
LEHMANN, K. B. & NEUMANN, R. O. (1927). *Bakteriologische Diagnostik*.
MIGULA, W. (1900). *System der Bakterien*.
STAPP, C. (1937). Weitere Beiträge zur Frage der Widerstandsfähigkeit verschiedenen Kartoffelsorten gegen Schwarzbeinigkeit und Knollennassfäule verursacht durch *Bacterium phytophthorum* Appel. *Angew. Botanik*, XIX, 2, 141–52.
ST JOHN-BROOKS, R. & BREED, R. S. (1937). Actions taken by the second International Microbiological Congress in London, 1936, regarding bacteriological nomenclature. *J. Bact.* IV, 445–7.
TOPLEY, W. W. C. & WILSON, G. S. (1936). *The Principles of Bacteriology and Immunity*, 2nd ed. pp. 217, 218 and 549.
WAKKER, J. H. (1884). Vorläufige Mittheilungen über Hyacinthenkrankheiten. *Bot. Centralbl.* XIV, 315–16.
WINSLOW, C.-E. A., BROADHURST, J., BUCHANAN, R. E., KRUMWEIDE, C., ROGERS, L. A. & SMITH, G. H. (1917). The families and genera of bacteria. *J. Bact.* II, 505–66.
WINSLOW, C.-E. A. *et al.* (1920). The families and genera of bacteria. *J. Bact.* V, 191–229.

(*Accepted for publication* 2 *May* 1942)

NOTE ON THE OCCURRENCE OF *PYTHIUM MAMILLATUM* MEURS IN BRITAIN

By H. DUERDEN, *Department of Biology, Chelsea Polytechnic*

For many years I have obtained *Pythium debaryanum* for class demonstration purposes from mustard or cress seedlings sold for salad uses. In February 1942, some mustard seedlings were purchased in Horley, Surrey, and were kept well damped in a Petri dish in anticipation of the usual appearance of *P. debaryanum*. After a few days the seedlings showed heavy fungal infection. At first zoosporangia, then, later, sexual organs of *Pythium* appeared. After fertilization, however, the oogonial walls developed protuberances, and it was clear that the plant was not *P. debaryanum*.

Measurements were made of the reproductive organs, and these, together with their characters, agree with those given by Meurs (1928) for *P. mamillatum*, which was described by Meurs as being parasitic on beet seedlings in Holland. Matthews (1931) later recorded the occurrence of this species in the United States from a collection of sandy soil from a pot in which Venus fly traps were growing in the University greenhouse at Chapel Hill (University of North Carolina).

Attempts to get the fungus into pure culture were made by washing infected hypocotyls with distilled water, then placing them in a Petri dish with distilled water and later transferring portions to potato agar plates, but these efforts failed. Rich growth of *Mucor racemosus* only resulted.

The exact source of the fungus could not be determined, as the vendor of the seedlings had several sources of supply and could not state with certainty where any particular sample originated. This, however, is the first record of the occurrence of *Pythium mamillatum* in Britain.

REFERENCES

Matthews, V. D. (1931). *Studies on the Genus Pythium*, p. 99. University of North Carolina Press.

Meurs, A. (1928).. Wortelrot, Veroorzaakt door Schimmels uit de Geslachten *Pythium* Pringsheim en *Aphomyces* de Bary. Dissertation, Baarn.

(*Accepted for publication* 4 *May* 1942)

THE NUMBERS OF FUNGI

By G. R. BISBY and G. C. AINSWORTH,
Imperial Mycological Institute, Kew

Those wishing to ascertain the number of fungi generally turn to Saccardo's *Sylloge Fungorum*. The twenty-five volumes of that work contain 78,360 numbered specific entries, distributed approximately as follows: Myxomycetes, 750; Phycomycetes, 1500; Ascomycetes, 26,150; Basidiomycetes, 24,700; Fungi Imperfecti, 24,200; Bacteria, 700; Fungi Fossiles, 360. Species described as new during the last twenty-three years—an average of about 1000 per year—have not yet been compiled; it is safe to say that the *Sylloge*, if up to date, would contain about 100,000 specific names. Saccardo's main task, however, had to be the compilation of new descriptions; addition, not subtraction. The figure for Myxomycetes is about double the correct number; that for *Fusarium* (over 500) nearly ten times the number now accepted, and so on.

Table I gives the approximate number of genera of fungi described up to 1940, and indicates the numbers accepted as 'good' by competent authorities.

Table 1. *Numbers of genera and species of fungi*

Group	Numbers of generic names considered: Good, total	Good, monotypic	Synonyms	Good species (approx.)
MYXOTHALLOPHYTA				
Acrasiales	9	3	2	25
Labyrinthulales	3	1	0	10
Hydromyxales	4	3	6	15
Myxomycetes	63	35	77	400
Total	79	42	85	450
PHYCOMYCETES				
Chytridiales	87	56	48	300
Lagenidiales	7	4	1	20
Blastocladiales	5	1	2	20
Monoblepharidales	2	1	2	10
Saprolegniales	24	8	9	110
Peronosporales	12	2	21	200
Mucorales	42	15	54	230
Entomophthorales	23	12	6	100
Incertae Sedis	8	7	4	10
Total	210	106	147	1000

Table 1 (*continued*)

Group	Numbers of generic names considered: Good, total	Good, monotypic	Synonyms	Good species (approx.)
ASCOMYCETES				
Endomycetales	43	22	23	140
Taphrinales	6	1	7	130
Eurotiales	48	28	36	100
Myriangiales	43	30	23	100
Dothideales	134	70	104	620
Hemisphaeriales	173	86	77	1000
Erysiphales	74	45	51	900
Hypocreales	124	63	108	800
Laboulbeniales	118	42	17	1500
Sphaeriales	385	172	430	4400
Hysteriales	16	4	15	130
Phacidiales	49	25	42	250
Helotiales	260	134	186	1400
Pezizales	54	13	96	500
Tuberales	27	9	22	140
Incertae Sedis	10	10	21	10
Total	1564	754	1258	12,120
BASIDIOMYCETES				
Ustilaginales	34	12	29	700
Uredinales	123	45	108	4600
Tremellales	53	20	54	500
Agaricales				
Exobasidiaceae	3	1	1	15
Thelephoraceae	32	9	88	900
Clavariaceae	7	0	25	300
Hydnaceae	14	2	71	300
Polyporcaeae	19	1	173	1000
Boletaceae	6	2	38	220
Agaricaceae	80	10	284	4100
Hymenogastrales	47	24	28	290
Phallales	26	11	36	85
Lycoperdales	21	7	29	220
Sclerodermatales	21	11	34	130
Nidulariales	7	3	8	70
? Gasteromycetes	2	2	9	—
Total	495	160	1015	13,430
FUNGI IMPERFECTI				
Sphaeropsidales	501	281	294	5200
Melanconiales	83	39	87	1000
Moniliales	629	301	452	4100
Mycelia Sterilia	21	10	29	200
Total	1234	631	862	10,500
FUNGI INCERTAE SEDIS	2	2	136	—
Grand total	3584	1695	3503	37,500

The number of species now known

While the figure of 37,000 species of Eumycetes is fairly conservative, there are two respects in which it is still too large: (1) it is probable that a third of the Fungi Imperfecti have named perfect stages (proved or unproved,

known or unknown); (2) many species of fungi are not based on morphology alone—the generally accepted criterion for specific distinction—but (as in *Meliola*, *Septoria*, *Ustilago*) on host as well. We estimate that about 3500 Ascomycetes, 2500 Basidiomycetes (especially rusts and smuts) and 3500 Fungi Imperfecti can be classified as 'host-species'. This indicates that there are about 34,000 species now known, of which no more than 25,000 are based on morphology.

Many species of fungi show more variability than their descriptions admit. Large herbaria or compilations show a suspiciously large number of 'species' represented by but one collection or record, often a century old. Those who examine saprophytic fungi from various parts of the world find again and again a few common species.

The number of species not yet described

Many tropical and other areas, still to be explored mycologically, will yield thousands of species (especially 'host-species') of fungi. Bessey in his *Textbook* (1935) remarks that few of the 5,000,000 or so species of insects have been examined for the presence of Laboulbeniales, and predicts that many new species, genera, and even families of these fungi will be found. On the other hand it is possible that more collections will eliminate some names by showing that certain species are more variable than had been thought. Yet from under our feet the Zoopagaceae—a whole new family—has recently come to light. Our guess is that about a third of the fungi are now known; in other words, that there are about 100,000 species.

The number of genera known

Nature may make species, but man has made the genera. By adding columns one and three in Table 1 the total number of generic names proposed up to 1940 is obtained; for all fungi (including Myxothallophyta), this figure exceeds 7000. (Clements and Shear, *The Genera of Fungi*, give some 4600 generic names of Eumycetes and 460 of lichens.)

It is probable that not more than one out of two proposed new genera is 'good', one out of three new species. Nearly half (47·2 %) of the genera accepted for Eumycetes, or for all fungi, are monotypic. Mycologists seem inclined to erect a new genus for each species except 'host-species'—and even for some of them. Phanerogamic botanists show a similar inclination: Willis (*The Course of Evolution*, 1940) records that 4853 of the 12,571 accepted genera of vascular plants (up to 1915) are monotypic, i.e. 38·6 %.

Many mycologists feel that the taxonomy of fungi is in greater need of synthesis than of more analysis; and a competent study of old genera and species, with much elimination.

The number of fungi in Britain

Table 2 gives the large figure of 9000 species of fungi (including Myxomycetes) recorded from Britain.

The *London Catalogue* lists 2362 Spermatophytes plus Pteridophytes now native in Britain. In comparing the two figures it must be remembered

that (1) mycologists include introduced fungi; (2) they seldom remove a name from their lists, and numerous 'species' have not been seen for a century; (3) perhaps 400 fungi are recorded in both perfect and imperfect stages; (4) many host-species are (rightly) included, and a large number of mistakes.

Perhaps 6000 of the 9000 names represent good species present in Britain to-day. We suggest that a new enumeration of British Fungi be started, based only on such specimens as can now be found, definitely identified, and preserved in available herbaria.

Table 2. *Number of species recorded from Britain*

Group	No.	Source of data
Myxomycetes	215	Lister's *Mycetozoa*
Phycomycetes	250	*Trans. Brit. Mycol. Soc.* v+50%
Discomycetes	900	,, ,, ,, ,, iv and suppls.
Pyrenomycetes	1423	,, ,, ,, ,, xxiv
Ustilaginales	70	,, ,, ,, ,, xxiv
Uredinales	330	M. Wilson *in litt.*
Higher Basidiomycetes	2689	Rea (1922), and suppls.
Coelomycetes	1800	Grove (1935, 1937)
Hyphomycetes	1208	*Trans. Brit. Mycol. Soc.* xxv
Dermatophytes	15	'Net' est. by P. H. Gregory, *in litt.*
Yeasts, etc.	100	Est. by writers
	9000	

(*Accepted for publication* 15 *May* 1942)

NEW AND INTERESTING PLANT DISEASES

By W. C. MOORE, *Plant Pathological Laboratory, Harpenden*

(With Plate I)

13. *Fusarium* disease of maize seedlings grown in nutrient solution

In the summer of 1937 a London firm, interested in methods of intensive cultivation, inquired about the suppression of moulds that were proving troublesome on cereal seedlings raised, for use as cattle fodder, by sprouting the grain in cabinets containing nutrient solutions. Efforts made to overcome the trouble by the adoption of better hygienic methods proved tolerably successful with barley, even when the seed was untreated. No improvement was obtained with maize, however, although, as an additional precaution, the seed was well washed with water and then soaked in a solution of potassium sulphide ($\frac{1}{2}$ oz. per gallon of water) for sixteen hours before being placed in the cabinets. This treatment retarded, but did not prevent mould development.

It was suspected that something other than saprophytic moulds must be present, and when specimens of the 'mouldy' maize seedlings were obtained towards the end of the year, nearly all of them were found to be vigorously attacked by *Fusarium moniliforme* Sheldon. The roots and frequently the bases of the young stems were brown and rotten, and the leaves were rapidly dying back from the tips. *Fusarium* was present in abundance on the affected parts, and here and there species of *Penicillium* and *Aspergillus* were also fructifying.

According to Wollenweber and Reinking (1935), *Fusarium moniliforme* is largely a 'warm-district' fungus, occurring as a parasite on maize mainly in tropical and subtropical areas. It often causes severe losses in the southern parts of the United States of America, and in Louisiana as many as 50 % of the seeds may be infected in some seasons. The surface of the seed becomes contaminated with spores, or the fungus may enter the grain and penetrate to any part of it.

The seed used in the sprouting cabinets was obtained from the Argentine and some of it must have been infected with *F. moniliforme*. Steeping the grain in potassium sulphide probably killed any spores on the surface of the seed, but had little or no effect on the mycelium in the tissues, and under the warm, humid conditions prevailing in the cabinets, the fungus developed rapidly and passed from the infected seed into the developing roots and stems. Moreover, the trays in the cabinets were so loaded with tightly packed grain that there was every opportunity for the fungus to pass rapidly from the seedlings primarily infected, to the healthy roots and stems developing from uninfected seed.

Investigations carried out in Illinois (Report, 1931) had indicated that 90 % of the *F. moniliforme* present in or on maize seed is killed when the seed is artificially dried in a Carrier air-conditioning apparatus at 43–54° C. (110–130° F.). Experiments along the same lines were therefore suggested to the firm and these were carried out. Within a month or two it was reported that the difficulties had been overcome, as far as the *Fusarium* was concerned, by heating the previously soaked seed to a temperature of 54° C. (130° F.) for twenty minutes. This treatment, however, had little or no effect on the subsequent development of *Penicillium* in the cabinets.

14. *Penicillium* rot of *Scilla* bulbs

Species of *Penicillium* have been found associated with rotting in bulbs of *Scilla* on several occasions. *Penicillium Gladioli* McCull. & Thom was identified by Miss McCulloch (Dean, 1930) on Dutch bulbs intercepted at Philadelphia in 1930. Later, MacFarlane (1939) found *P. cyclopium* Westl. causing a partial or complete rot of bulbs of *Scilla campanulata* var. *albida* imported into Scotland from Holland, and she showed that this fungus acted as a wound parasite of *Scilla* bulbs under moist conditions, when the storage temperature was relatively high (16–20° C.). Her results were confirmed by Singh (1941), who isolated the same species from imported bulbs of *S. nutans* and *S. campanulata*, as well as from bulbs of bluebells collected in woods in England. He proved, too, that the fungus from *Scilla* could attack wounded *Lilium* and *Iris* bulbs, and that *Penicillium corymbiferum* from rotting bulbs of *Lilium regale* was pathogenic to damaged *Scilla* bulbs.

In September 1941 I found a species of *Penicillium* associated with a storage rot that had affected some 10 % of 8000 bulbs of *Scilla patula excelsior* and *S. hispanica alba* grown in Buckinghamshire. Large, lateral, sunken lesions up to $\frac{3}{4}$ in. across, and often coalescing, were present on most of the diseased bulbs, but occasionally the basal plate only was affected. The diseased areas were frequently completely covered with a copious growth of *Penicillium*, but where this was absent or sparse, the lesions were pale brown and the outer skin was puckered into yellow folds or blisters. In some bulbs the rot was superficial, extending only about $\frac{1}{8}$ in. into the outer scale, with the collapsed cells forming a buff-coloured, spongy layer; in others, it was wet, soft, deep brown, and penetrating. A single species of *Penicillium* was isolated in pure culture from the surface of the lesions and from the rotted tissues, and Mr G. Smith kindly identified it for me as a strain of the *corymbiferum-hirsutum* group. On Czapek agar it produced numerous very characteristic blood-red drops. The colour on this medium was a little less bluish than that of typical *corymbiferum*, and probably clearer than that of *hirsutum*. Smith (*in litt.*) agrees with Thom (1930) that these two forms can be regarded as different strains of the same species. According to Thom, the original description of *Penicillium hirsutum* Dierckx (1901) was worthless, but the species was adequately described by Biourge (1923), who, to judge from his account, probably had access to authentic material. If so, the correct name of the fungus is *P. hirsutum* Dierckx, despite the fact that *P. corymbiferum* Westling (1911) antedates Biourge.

15. Bulb canker of garlic (*Allium sativum* L.), caused by *Helminthosporium Allii* Campanile

In April 1942 Mr C. J. Hickman sent me a few diseased cloves (bulblets) of white garlic (*Allium sativum* L.) that had been picked out from a consignment of bulbs imported from the Argentine and destined, in part, for planting in Worcestershire. The amount of disease present in the consignment was slight for, in half a hundredweight of bulbs examined, Mr Hickman had found less than 1 % affected.

The most striking feature of the disease on the individual clove was the occurrence of a black, sunken, canker-like area, $\frac{1}{2}$ in. or so across, at the top or on the side of the fleshy scale, immediately below the membranous, silky white, enveloping scale (Pl. I, fig. 1). The black appearance was due to the presence on the surface of the lesion of a dense felt of mycelium and spores of a species of *Helminthosporium*. In one or two instances the whole of the inner surface of the outer membranous scale had become sprinkled with spores and mycelium from the canker lesion, and externally the whole clove looked blackened. On some cloves, however, the fungus had not fruited and the lesion was then pale brown or brown with a greyish centre.

The conidiophores of the fungus were comparatively rigid, straight or bent, brown, septate, up to 120μ or more long, and about 6μ wide at the base. The conidia were acropleurogenous, a single one being present at each bend or joint of the conidiophore as well as at its tip. The conidia (Pl. I, fig. 2) varied much in shape and size. The majority were long, cylindric, smooth, usually tapering at the rounded ends, brown, with 4–8 (usually 4–5) transverse walls, not constricted at the septa, and measuring 30–41 × 9–11μ (average 35 × 9·5μ). Many conidia, however, were shorter and relatively broader (21–26 × 10–12μ), ellipsoidal, with only 2–3 transverse walls, while a comparatively small number were quite irregular in shape, being curved and 'waisted', or bent abruptly in the middle or towards one end to give a broad and shallow V-shape or even a Y-shape. Occasionally these abnormal conidia showed a single longitudinal or radial wall, and in one or two instances the penultimate cell had given rise to a typical brown septate conidiophore about 50μ long. The characters of the fungus, and the symptoms of the disease associated with it, corresponded very closely to those described and illustrated by Campanile (1924 *a*, *b*) for *Helminthosporium Allii* Campanile, with which the present fungus is believed to be identical.

Campanile described a new disease of garlic occurring in the Fucino district of Italy, and showed that it was due to a species of *Helminthosporium*, which she regarded as new and named *H. Allii*. The disease attacked the bulbs, leaves and flowering scape of white garlic, especially the larger bulbs and more vigorously growing plants. It was not seen on red garlic, though this variety became infected when cloves of it were inoculated artificially, if the outer covering scale was first removed. Even then, however, the red variety showed some resistance to the fungus. Campanile referred to, and briefly described, an unidentified species of *Pleospora* that was commonly present on garlic plants attacked by the *Helminthosporium*. She thought the

Fig. 1

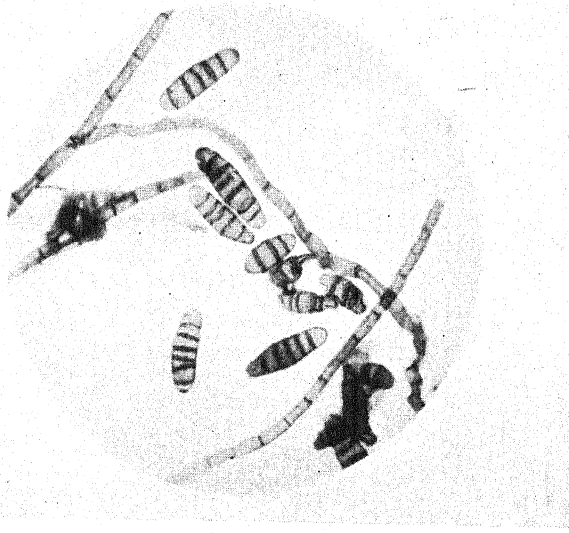


Fig. 2

Photos by W. F. Buck

two fungi were probably related, but did not succeed in obtaining the *Pleospora* in pure culture. No perithecia were present on the diseased cloves I examined.

I could trace no other record of *Helminthosporium Allii*, but a bulb rot of garlic due to an unidentified species of *Helminthosporium* was reported from Texas in 1937 (Wood & Nance, 1939) and in the two succeeding years (Nance, 1940 & 1941), and some years before, Walker and Lindegren (1924) had referred to a small-spored species of *Helminthosporium* that commonly caused dark-coloured blotches on the outer scales of White Globe onions in America, though it was never seen on the coloured varieties.

REFERENCES

Biourge, P. (1923). Les moisissures du groupe *Penicillium* Link. Étude monographique. *La Cellule*, xxxiii, fasc. 1, 157.

Campanile, G. (1924*a*). Su di una nuova malattia dell' aglio dovuta ad '*Helminthosporium allii*' nov.sp. *Nuova Ann. Minist. Agric.* iv, 87–106.

Campanile, G. (1924*b*). Richerche sopra le condizioni di attacco e di sviluppo di *Helminthosporium allii* su aglio. *Staz. sperm. agrar. Ital.* lvii, 413–28.

Dean, H. S. (1930). Plant quarantine notes. *Plant Dis. Reptr.* xiv, 247.

Dierckx, R. P. (1901). Un essai de révision du genre *Penicillium* Link. Note préliminaire. *Ann. Soc. sci. Brux.* xxv, 83–89.

MacFarlane, Christina S. (1939). A rot of Scilla bulbs caused by *Penicillium cyclopium* Westling. *Trans. bot. Soc. Edinb.* xxxii, 542–7.

Nance, Nellie W. (1940). Diseases of plants in the United States in 1938. *Plant Dis. Reptr. Supp.* cxix, 198.

Nance, Nellie W. (1941). Diseases of plants in the United States in 1939. *Plant. Dis. Reptr. Supp.* cxxviii, 250.

Report (1931). A year's progress in solving farm problems of Illinois, 1930–31. *Rep. Ill. agric. Exp. Sta. for year ending* 30 *June* 1931, xliv, 214–17.

Singh, B. (1941). Bulb rot of *Scilla nutans* caused by *Penicillium cyclopium* Westling. *Trans. Brit. myc. Soc.* xxv, 194–9.

Thom, C. (1930). *The Penicillia*, p. 425.

Walker, J. C. & Lindegren, C. C. (1924). Further studies on the relation of onion scale pigmentation to disease resistance. *J. agric. Res.* xxix, 510.

Westling, R. (1911). Über die grünen Spezies der Gattung *Penicillium*. *Svensk. Bot. Tidskrift*, v, 82–90. See also *Arkiv for Botanik*, ii, 1–156.

Wollenweber, H. W. & Reinking, O. A. (1935). *Die Fusarien, ihre Beschreibung, Schadwirkung und Bekämpfung*, p. 297. Berlin.

Wood, Jessie I. & Nance, Nellie W. (1939). Diseases of plants in the United States in 1937. *Plant Dis. Reptr. Supp.* cx, 276.

EXPLANATION OF PLATE I

Fig. 1. Clove (bulblet) of *Allium sativum* L. with apical part attacked by *Helminthosporium Allii* Campanile. The outer enveloping skin has been removed.

Fig. 2. Spores and mycelium of *Helminthosporium Allii* Campanile. × 350.

(*Accepted for publication* 10 *June* 1942)

TWO NEW SPECIES OF *ASPERGILLUS*

By GEORGE SMITH, *from the Division of Biochemistry, London School of Hygiene and Tropical Medicine, University of London*

(With Plates II and III)

Aspergillus avenaceus n.sp. (Cat. No. 155). Pl. II, figs. 1–3.

The fungus was isolated in March 1938 by Dr G. E. Turfitt, then working in this Department, from seed peas.

In colour and general appearance of the conidial heads the new species strongly resembles *A. ochraceus* Wilhelm or, perhaps more nearly, *A. sulphureus* Fres. The character of the stalks, however, precludes relationship with the latter group. They show no trace of roughness, even under the highest magnification, but are more or less brittle, with a tendency to split longitudinally when sharply bent or broken, suggesting affinity with the *A. niger* series. The most striking feature of the mould is the production of large black sclerotia, quite unlike the usual types found in either the *A. ochraceus* or the *A. niger* series.

Dr Charles Thom, of the U.S. Department of Agriculture, has very kindly examined the fungus and suggests that its nearest relation is *A. alliaceus* Thom & Church, from which, however, it differs materially. It appears to be a further addition to the series of species, including *A. Schiemanni* Thom & Church, *A. cinnamomeus* Schiemann, and possibly some of the pure white forms at present included in *A. candidus* Link, which are morphologically related to the *A. niger* series, but in which the dark colouring matter is almost or entirely absent. Dr Thom also reports that *A. alliaceus*, in which the sclerotial phase usually predominates, may be induced, by suitable 'poisoning', to produce abundant conidial heads. *A. avenaceus*, on the other hand, when grown on most solid culture media, is mainly conidial with comparatively few sclerotia, but becomes almost entirely sclerotial on Czapek's solution containing glucose as source of carbon.

Diagnosis

Aspergillus avenaceus sp.nov. coloniis in agaro Czapekii late crescentibus, paulo floccosis, albis dein luteolis aut avenaceis, aliquando leviter viridulis sed numquam vere viridibus, reverso carneolo; capitulis globosis, 400–600 μ diam., in cultis senibus incompositis cum diametris maximis ad 1000 μ; stipitibus glabris, fractis cum fissione in longitudinem, 4–5 mm. longis et 18–30 μ diam., parietibus 2·5–4 μ crassis; vesiculosis globosis, interdum leviter applanatis, crassimuratis, ad 185 μ diam.; sterigmatibus primariis 22–50 × 6 μ, secundariis 11–13 × 4 μ; conidiis glabris, ellipsoideis, 4–6 (6·5) × 3·2–4 μ; sclerotiis nigris vel griseofuscis, plerumque prope ampulliformibus, saepe bifurcis, 2–3 mm. long., frequentissimis in cultis in aqua Czapekii glucoso commixto.

Fungus in seminibus exsiccatis *Pisi sativi* inventus, non parasiticus.

Colonies on Czapek agar (with saccharose) spread rapidly, at first white and slightly floccose, then dull yellow to ochraceous, often with a slight greenish tinge but never definitely green, with large prominent conidial heads on long stalks; reverse pale dirty pink; sclerotia appearing usually in seven to ten days, not very numerous, often produced in concentric zones.

On Czapek agar with glucose, sclerotia are much more numerous and often larger.

On wort agar or potato agar colonies spread rapidly, with abundant production of conidial heads and with sclerotia appearing only after several weeks, and then somewhat sparsely.

On Czapek's solution, with 5 % glucose as source of carbon, growth consists at first of a thin mat of dirty white, slightly floccose mycelium, soon followed by the development of enormous numbers of black sclerotia, covering the original mycelial felt almost completely, with conidial heads produced tardily and only in isolated patches.

On Raulin-Thom solution (i.e. Raulin's solution with ammonium tartrate in place of ammonium nitrate) colonies are floccose, sporing tardily and somewhat sparingly, with very large viscous drops, and with the solution gradually becoming exceedingly viscous; no sclerotia are formed.

Conidial heads globose, 400–600 μ in diam., tending to split in age to form several roughly columnar masses of conidial chains, with greatest diam. up to 1000 μ; stalks without any trace of pitting or roughness, tending to split when bent or broken, 4–5 mm. long and 18–30 μ in diam., with walls 2·5–4 μ thick; vesicles globose, sometimes slightly flattened, thick-walled, up to 185 μ in diam.; primary sterigmata varying considerably in length in different heads, 22–50 × 6 μ, secondary sterigmata more uniform, 11–13 × 4 μ; conidia smooth, definitely ellipsoid, 4–6 (6·5) × 3·2–4 μ; sclerotia dark greyish brown to black, irregular but mostly more or less flask-shaped, often forked and resembling two-necked perithecia, 2–3 mm. long.

Species related to *A. alliaceus* Thom & Church but distinguished therefrom by its abundant production of conidial heads and by its larger, definitely ellipsoid conidia. The specific name chosen as descriptive of the conidial colour.

Aspergillus proliferans n.sp. (Cat. No. 82), Pl. II, fig. 4 and Pl. III, figs. 5–6

This species was received in October 1927 from the British Cotton Industry Research Association. It was originally isolated from cotton, but its exact history is unknown.

An examination at the time showed the presence of scanty conidial heads of the normal *Aspergillus* type, and of numerous sporing structures which apparently bore little resemblance to any *Aspergillus*. Pl. II, fig. 4 and Pl. III, fig. 5, from photomicrographs taken in January 1928, show the normal and abnormal types of head. Recent study of the mould has shown that it is morphologically stable, and still shows all the characteristics it had when first isolated. The abnormal heads are now interpreted as owing their bizarre appearance to variously transformed sterigmata. The general

appearance of colonies, the rate of growth, the structure of normal conidiophores and the size and markings of the conidia all suggest affinity with the *A. glaucus* group. Proliferation is fairly commonly observed in species of this group, but it is unusual to find, as in the new species, abnormal heads predominating. No perithecia have been observed, but this does not necessarily preclude relationship with the *A. glaucus* group. Recent work by Thom and Steinberg (1939, 1940) has shown that stable mutants from various species of *Aspergillus* can be obtained by chemical stimulation, the mutants from *A. glaucus* showing partial or total suppression of the perfect stage, and it is suggested that non-perithecial strains which are periodically isolated from natural sources have arisen in a similar way.

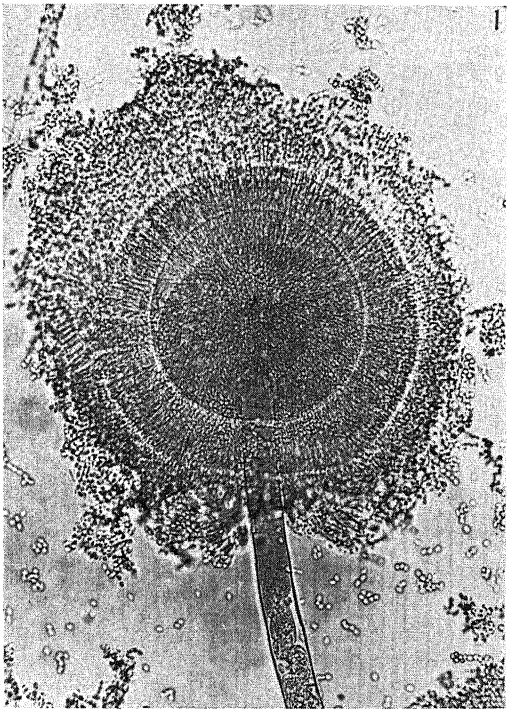
Diagnosis

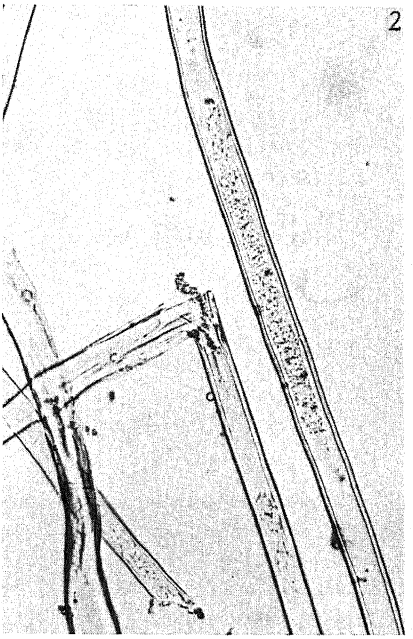
Aspergillus proliferans sp.nov., coloniis in agaro Czapekii lentissime crescentibus, primo albis dein lutescentibus denique glaucis, reverso luteobrunneo; in musto ex hordeo cum agaro celeriter sed tamen lente crescentibus, mycelio aerio albo dein luteo aurantioque, floccoso, cum partibus fertilibus glaucis dein griseis tarde apparentibus, reverso luteo; capitulis veris laxis radiatis; stipitibus glabris, ferme septatis, cum parietibus tenuibus, 4–14μ diam.; vesiculosis subglobosis vel obconicis vel solum extremis stipitibus leviter crassatis; sterigmatibus in una serie, 8–11 × 3·5–6μ sed saepe elongatis, septatis, parvis capitulis secundariis ferentibus, vel cum partibus superioribus inflatis, ad 20μ diam.; conidiis globosis subglobosisve, asperulis, fuscis, 5–9·5μ diam.; peritheciis ignotis.

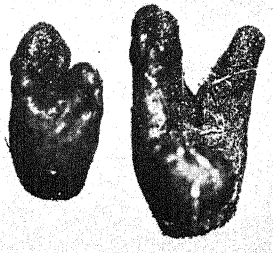
Fungus *A. glauco* propinquus, in gossypio inventus, British Cotton Industry Research Association, Mancunii.

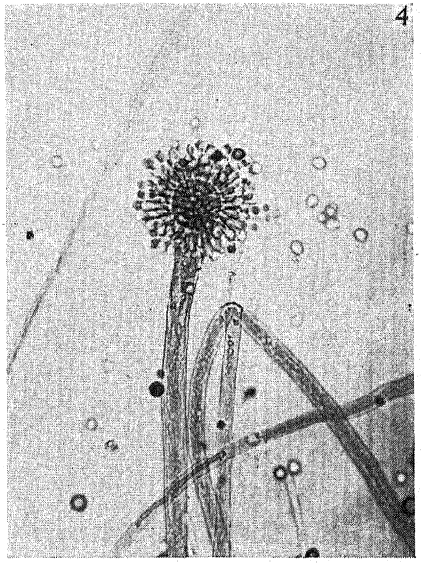
Colonies on Czapek agar spreading very slowly, with growth at first largely submerged, then with matted floccose aerial mycelium, white changing to yellowish shades, sporing tardily, with conidial areas grey-green, reverse yellowish brown; on wort agar growing slowly but better than on Czapek, with mycelium white then yellow and finally orange and tardy development of grey-green to grey conidial areas, becoming more deeply floccose in age especially at shallow end of slope, reverse yellow; normal conidial heads loosely radiate; stalks smooth, thin-walled, usually with one or two septa, 4–14μ diam.; vesicles occasionally almost globose, more frequently obconical or mere thickenings of the ends of the stalks, up to about 20μ in diam.; sterigmata when normal, in one series, 8–11 × 3·5–6μ, often elongate, septate and bearing small secondary heads, frequently resembling heads of monoverticillate *Penicillia*, or with upper portion much swollen and appearing almost as a very large, thick-walled conidium with long connective, up to 20μ diam., with normal and swollen sterigmata often appearing in the same head; conidia globose or subglobose, rough, fairly dark-coloured, 5–9·5μ in diam.; perithecia not found.

Species related to the *A. glaucus* series, and abnormal in lacking the perfect stage and in the unusual tendency to proliferation of sterigmata.

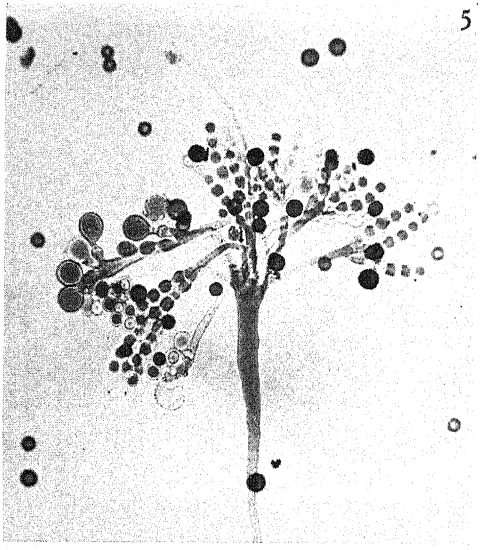

1


2

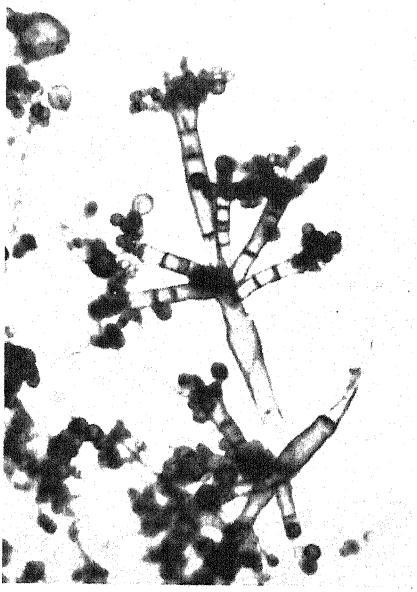

3


4

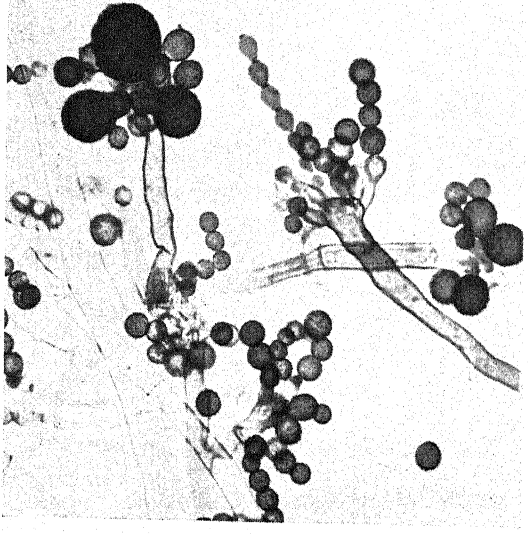
5



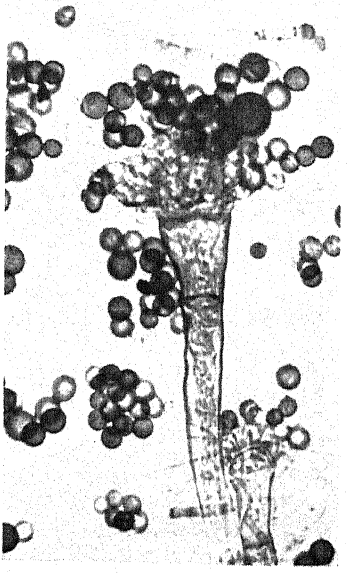
6



7



8



REFERENCES

STEINBERG, R. A. & THOM, C. (1940). Chemical induction of genetic changes in Aspergilli. *J. Heredity*, XXXI, 61–3.

THOM, C. & STEINBERG, R. A. (1939). The chemical induction of genetic changes in fungi. *Proc. Nat. Acad. Sci.* (*U.S.A.*), XXV, 329–35.

EXPLANATION OF PLATES

Fig. 3 is from a photograph of dry, unmounted specimens. All the remaining figures are from photographs of specimens mounted in lacto-phenol.

PLATE II

Fig. 1. *Aspergillus avenaceus*. Typical head. × 150.

Fig. 2. *A. avenaceus*. Broken stalk showing characteristic splitting. × 250.

Fig. 3. *A. avenaceus*. Sclerotia. × 12.

Fig. 4. *A. proliferans*. Normal type of head. × 250.

PLATE III

Fig. 5. *A. proliferans*. Very abnormal head. × 250.

Fig. 6. *A. proliferans*. Head with cluster of secondary stalks in place of sterigmata. × 250.

Fig. 7. *A. proliferans*. Small head with normal sterigmata and head with swollen cells. × 500.

Fig. 8. *A. proliferans*. Head with one swollen sterigma, the rest normal. × 500.

(*Accepted for publication* 27 *June* 1942)

THE MEASUREMENT OF PLANT DISEASES IN THE FIELD

PRELIMINARY REPORT OF A SUB-COMMITTEE OF THE SOCIETY'S PLANT PATHOLOGY COMMITTEE

By W. C. MOORE

(With 2 Text-figures)

In 1933 the Society's Plant Pathology Committee organized a symposium on the measurement of disease intensity, at which methods devised by research workers for use in investigating certain well-known diseases were described and discussed (*Trans. Brit. myc. Soc.* XVIII, 1933, 174). Since that time the need to improve existing methods of recording the amount of disease, in order to obtain precise information about the general prevalence and intensity of diseases in Great Britain in relation to locality, season, soil and other factors, has become increasingly recognized. In an effort to satisfy this need, the Plant Pathology Committee called a special meeting at Rothamsted (Harpenden) in February 1941 for a full discussion on the subject, to which a number of plant pathologists were invited. At this meeting it was agreed that the Committee should attempt to evolve simple but reliable standard methods of recording disease quantitatively in the field; and a sub-committee consisting of W. Buddin (Secretary), F. C. Bawden, R. W. Marsh, W. C. Moore and the Secretary of the Plant Pathology Committee (P. H. Gregory) ex officio, was appointed to make provisional recommendations for immediate adoption.

It was realized from the start that tentative proposals, necessarily based mainly on theoretical considerations, might need to be modified considerably in the light of practical experience extending perhaps over several years. Appreciating this, the sub-committee prepared a flexible scheme which, while acting as a framework and serving as a guide, permitted ample scope for individuality and allowed for necessary adjustments. The scheme was explained at a general meeting of the Society held in April (Bawden, 1941), and shortly afterwards a letter asking for active collaboration was sent to those interested, together with copies of the proposals for 1941. Printed forms specially designed for recording results were also made available. As a result, over 1200 estimates of disease intensity were received during 1941, and the sub-committee gratefully acknowledges the help given to them in this work by G. C. Ainsworth, A. Beaumont, S. D. Garrett, Miss M. D. Glynne, D. E. Green, C. J. Hickman, R. Hull, E. C. Large, M. H. Moore, N. C. Preston, I. F. Storey, R. E. Taylor, A. G. Walker, Mrs M. A. Watson, J. H. Western, W. A. R. Dillon Weston, R. K. S. Wood* and R. C. Woodward.

* Mr Wood's observations were carried out during the three months' tenure of a special grant made by the Ministry of Agriculture and Fisheries, to whom grateful acknowledgement is made.

The methods employed in 1941

Whether the measurement of disease is considered as an end in itself, regardless of the uses to which the results might be put, or as a means of estimating, for instance, the rate of progress of disease, the efficacy of protective control measures or the monetary losses due to diseases of economic plants, the methods employed should be accurate. One of the chief aims of the sub-committee, therefore, was to devise quantitative methods based on crop sampling. Such methods, though to be preferred wherever possible, might consume too much time to be of practical value when large numbers of crops are to be examined. It is therefore also desirable to test the reliability of rapid visual estimates against the sampling methods, much in the same way as Horsfall and Heuberger (1942) have done for a leaf disease of tomato. For general purposes it is essential above all to make sure that the results obtained on the same crops by different observers, using the same or different methods, are strictly comparable.

The work carried out in 1941 was regarded as mainly exploratory in nature. Attention was directed to six diseases of crops important in war time, namely, Loose Smut of wheat, Blight and Virus diseases of potato, Virus Yellows and Downy Mildew of sugar beet, and Brown Rot of apple. They were selected in part because of ease in recording. Observations on Take-All and Eyespot of wheat, and on apple Scab, were also invited because of their special appeal in current research.

It is scarcely necessary to give here full details of the sampling methods employed; they were regarded as tentative and were, indeed, modified during and after the season, as occasion demanded.

The same general procedure was recommended for potato, sugar beet and wheat. Two traverses were made, and ten samples taken on each traverse. For potato and sugar beet the sample consisted of ten consecutive plants in a drill, and the ten samples were taken at convenient distances along the diagonals of the field. With wheat, each sample consisted of two one-yard lengths of drill row, consecutive but in adjacent rows. Moreover, in order to avoid unnecessary damage to the crop, the traverses were taken in the direction of drilling instead of along the diagonal. The traverses were begun from the side of the field at points one-fifth and four-fifths of the width of the field, the first sample was taken not less than fifteen paces from the edge of the field and, after each sample, the observer side-stepped three paces and proceeded along the row to the next sampling place. With all diseases except potato blight it was sufficient to record the numbers of infected and healthy plants (or tillers) in each sample. For potato Blight each plant in the sample was given a symbol from 0 to 6, depending on the numbers of Blight spots present on the leaflets or, at the higher levels, on the amount of leaf area destroyed.

Brown Rot of apple was recorded a fortnight or so before harvest. A count was taken of the number of affected apples among fifty fruits chosen at random from each of ten trees taken at random. Sampling for apple Scab was carried out in July and was based on a minimum of five hundred leaves collected by picking fifty leaves at random from each of

ten trees, scattered through the orchard. The leaves were graded by means of the Tehon scale (Tehon & Stout, 1930).

The figures for intensity of disease obtained by these sampling methods were recorded on specially printed forms (Fig. 1), together with the locality, variety, size of field, stage of development of the plants (recorded as symbols A, B, C, etc., each corresponding to a standard description), control measures and other relevant information. Reports were made on all fields examined, whether or not disease was present in them.

PLANT DISEASE REPORT

Crop Date Disease

Address

Variety

Size of Field

Stage of Development of Plants

Control measures:—

Infection Data:—

Remarks:—

Fig. 1.

The results obtained

As already indicated, the primary object of the Committee is to devise, test, and ultimately to recommend methods of measuring disease. The extent to which any methods evolved are approved and adopted as standards, however, will depend mainly on the results they yield and the uses to which those results can be put. It may therefore be profitable to summarize the encouraging results obtained in 1941 and to illustrate a few of the ways in which they might be used to advantage.

Potato Blight (*Phytophthora infestans* (Mont.) de Bary). The year was a favourable one for observation on this disease, and after the large number of reports received from collaborators had been considered clear indications of future possibilities became apparent.

The date of attack. Apart from their intrinsic value, the dates on which Blight is first recorded, or when it reaches a certain intensity in different districts, provide evidence for or against the belief that Blight begins in the west and spreads gradually to the east and north. First records were noted in Cornwall (28 July), Evesham (before 2 September), Reading (14 August), Harpenden (20 August) and Spalding (22 August), and the approximate dates when most plants of a variety of medium susceptibility were one-third defoliated by Blight were recorded from West Devon (30 August), Central Devon (23 August), East Devon (6 September), Evesham (14 September), Reading (27 August), Harpenden (6 September), and Spalding (9 September).

The course of epidemic attacks. Much greater scope is afforded when several records are taken on the same crop. Fig. 2 shows a graph in which the

degree of intensity of attack is plotted against time for four districts. Only the data for one field of Majestic in each district is included, and despite the fact that the recording method had not been stabilized and the frequency of observation varied with the district, the graph clearly demonstrates the relatively late appearance and rapid spread of Blight in 1941 in all four areas. The available records on the course of the disease at the Seale-Hayne Agricultural College in 1932 and 1937 are included to show the contrast in slope and position along the time scale that can be expected in other seasons. It is obvious that with the adoption of standard methods of

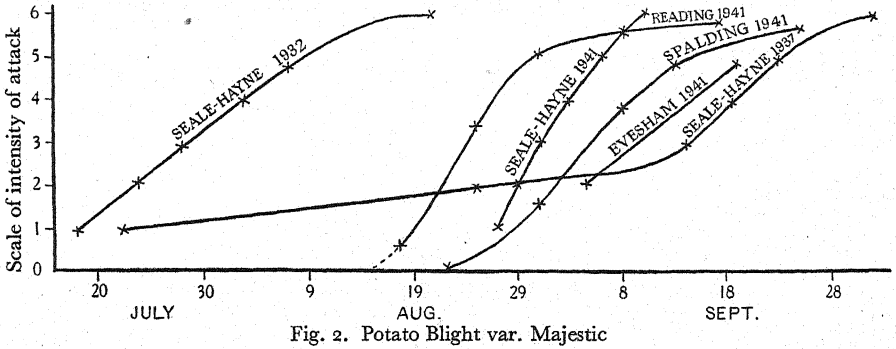


Fig. 2. Potato Blight var. Majestic

recording, applied in many more districts, and with the accumulation of similar graphs over a period of years, invaluable information can be collected about potato Blight or, indeed, about many other epidemic diseases.

Varietal susceptibility in the foliage. From the records obtained it was possible to construct the following list of varieties arranged in descending order according to the susceptibility of the foliage to Blight. The list is compiled mainly from the records made in south-west England, but the position of some varieties was confirmed in other districts.

Early varieties	Second early and main-crop varieties	
Arran Pilot, D, E	King Edward, D, E, R	Arran Banner, D, E, R
May Queen, D	Up-to-date, D	Golden Wonder, D
Epicure, D	British Queen, D	Red Skin, E
Sharpe's Express, D	Dunbar Rover, R	Arran Chief, E, R
	Majestic, D, E, R, S	Gladstone, D, E, R
	Doon Star, D, E, S	Dunbar Archer, D
	Great Scot, D, E, R	Kerr's Pink, D
	Red King, D	President, D

D=Devon and Cornwall; E=Evesham; R=Reading; S=Spalding area

Relative susceptibility of Scotch and once-grown seed. In five well-separated fields in Berks and Oxon it was possible to compare the development of Blight on adjacent crops of Majestic grown from fresh Scotch and English once-grown seed. The results showed that in general Blight was slightly worse on the once-grown crops.

There is no doubt that still further information of practical value about

Blight can be deduced from records made on a common plan. For instance, the observations carried out in Devon and Cornwall provided most significant and concise data for comparing the protective effects of different spray treatments.

Potato Virus Diseases. 119 crops were examined for Leaf Roll, Severe Mosaic (secondary infection with potato virus *Y*) and Leaf-Drop Streak (primary infection with potato virus *Y*). They cannot be regarded as a representative sample of the potatoes grown in England, because they contained only seven crops from twice-grown seed, but they yielded results from which trustworthy conclusions can be drawn.

Table 1

Seed	Disease category (% plants infected)	Number of crops in each category: Leaf Roll	Severe Mosaic	Leaf-Drop Streak	Total severe disease
	SOUTH OF THE WASH				
Certified (32 crops)	0·0–0·4	5	27	22	3
	0·5–2	16	3	6	13
	2·1–8	9	1	4	12
	8·1–20	1	1	0	3
	21 –60	1	0	0	1
Once-grown (41 crops)	0·0–0·4	3	22	21	1
	0·5–2	12	16	7	9
	2·1–8	12	3	5	12
	8·1–20	8	0	7	8
	21 –60	6	0	1	11
Twice-grown (7 crops)	0·0–0·4	0	1	—	0
	0·5–2	0	4	—	0
	2·1–8	1	1	—	0
	8·1–20	1	0	—	0
	21 –60	3	0	—	4
	61 –100	2	1	—	3
	NORTH OF THE WASH				
Certified (23 crops)	0·0–0·4	12	17	21	8
	0·5–2	10	5	2	11
	2·1–8	1	1	0	4
Once-grown (16 crops)	0·0–0·4	5	9	16	3
	0·5–2	5	5	0	4
	2·1–8	1	2	0	4
	8·1–20	3	0	0	3
	21 –60	2	0	0	2

Leaf Roll was by far the most important disease in the seed at the time of planting, thus confirming general field observations that there was little Leaf-Drop Streak in 1940. By August 1941, however, there was a considerable amount of Leaf-Drop Streak in the south. Table 1 distinguishes the crops grown north and south of the Wash and shows the number of crops derived from each kind of seed, and the disease category into which they were placed. The average of total severe virus diseases in the south in certified, once-grown and twice-grown stocks was 4, 15 and 54% respectively; in the north in certified and once-grown stocks it was 1·3 and 8·5%.

Sugar-Beet Virus Yellows. The disease was late in appearing. During September and October thirty-four crops were recorded in Berks, Hants, Herts and Lincs. No field was free from the disease, nine showed less than 2 % of the plants infected, sixteen 2–6 %, seven 6–20 % and two over 20 %.

Wheat Take-All and Whiteheads (*Ophiobolus graminis* Sacc.). Eighty crops were examined; of these sixty-five had no plants with Whiteheads, six had less than 5 % of the plants affected, two had 6–20 % and seven 20–60 %. Forty-five of the crops were on newly ploughed grassland; of these forty were free from the disease and only one had more than 5 % of the plants affected.

Wheat Eyespot (*Cercosporella herpotrichoides* Fron). The proportion of 189 wheat crops examined that showed lodging in conjunction with Eyespot increased strikingly towards the east of the country, and was much greater in fields where wheat had been grown frequently in the past. In Wales less than 4 % of the wheat fields were infected, in the West Midlands 25 %, in the East Midlands 60 % and in East Anglia 85 %. The distribution of infection and its correlation with lodging are shown in Table 2. The records were taken shortly before harvest.

Table 2

% of straws infected	0	1–20	21–70	71–100
No. of fields in category	76	53	38	22
% area of crops lodged	3	12	13	37

Apple Scab (*Venturia inaequalis* (Cooke) Wint.). Six observers co-operated and twenty-two reports were received from Berks, Cambs, Hants, Kent, Northants and Worcs. Cox's Orange Pippin, Worcester Pearmain and Bramley's Seedling were the chief varieties recorded. The Tehon scale (Tehon & Stout, 1930) was used throughout for leaf grading, but it proved laborious and is probably erratic where a relatively small sample (500) of leaves is taken.

Miscellaneous. Reports were also received for the following diseases, but in numbers too small to permit analysis: Black Leg (three) and Dry Rot (three) of potatoes, Loose Smut of wheat (sixteen) and Brown Rot of apple (five).

Modified methods for 1942

As was to be expected, the experience gained in 1941 paved the way for various improvements in the methods employed. The revised sampling methods, which were circulated for use in 1942, are given below, but they, too, are to be regarded merely as another stage towards the ultimate goal. The same diseases were chosen, but the methods were simplified and the number of disease categories reduced. The symbols to be adopted in recording all diseases are approximations to a percentage infection; for virus and cereal diseases this involves a percentage of affected plants and heads respectively, and for foliage diseases a percentage of affected leaf area. Only crops with more than 1 % of disease estimated in this manner need to be sampled, and rapid visual methods for determining the dividing line have been added.

Cereals. Wheat Loose Smut, and Take-All, Eyespot and Brown Foot-Rot as far as they have caused Whiteheads, can all be recorded from the same traverses through the field. Two traverses should be made taking ten samples on each traverse, working along the drills but side-stepping three paces after each sample. The sample should consist of two one-yard lengths of drill row, consecutive but in adjacent drills. When Whiteheads are found the plants should be pulled up to determine whether the stem bases or roots are blackened (Take-All), or whether the Whiteheads are due to Eyespot, *Fusarium*, or a combined attack; a closer search should also be made along the sample for plants killed before heading. The number of affected plants, together with the larger number of affected tillers or heads produced by them, should be recorded for each pathogen.

Category %	Limits
<0·01	Less than 1 head in 50 square yards
<1·0	Less than 2 heads in 1 square yard
>1·0	More than 2 heads in 1 square yard

If more than 1 % is estimated counts should be made.

Smuts of all cereals can also be estimated by counts of suitable samples when the crops are in stook, taking 500–1000 ears as a minimum for each field.

Potato Blight. Ten samples should be taken at suitable distances in the general direction of each diagonal of the field. It is not possible to stipulate a definite number of plants for an individual sample because of variations in growth, but care should be taken to see that neither leaves that would normally be moribund, nor plants attacked by Black-Leg or Leaf-Drop Streak, are included.

Category %	Limits
0·0	Not seen on field
< 0·1	One or two spots usually visible from any position, or the same percentage might be given by a few developing foci
< 1·0	About ten spots per plant, or general light spotting
<25	Nearly every leaflet with lesions, plants still retaining normal form; field may smell of blight
<50	Half of leaf area destroyed by blight
<75	Three-quarters of leaf area destroyed by blight
100	Leaves completely destroyed by blight

It is suggested that in each observer's area each year the progress of Blight should be recorded from the earliest stages on at least one crop of each of the varieties King Edward and Majestic in terms of the agreed scale of Blight grades. Once the epidemic has started in an area as many other crops as possible should be recorded.

Virus Diseases (sugar-beet Yellows, potato Leaf Roll, Severe Mosaic and Leaf-Drop Streak). Below 1 % can be estimated visually. When more than 1 % of disease is present counts should be made on random samples on each of two diagonal traverses of the field. Some observers prefer a sample of thirty plants (ten in each of three rows chosen consistently from the sampling position), others a sample of one hundred plants (fifty on either side of the drill up which the observer walks). At least five hundred plants should be recorded on each traverse of the area. Potato primary Leaf Roll

and Leaf-Drop Streak should be recorded separately from secondary Leaf Roll and Severe Mosaic.

Category %	Limits: sugar beet	Limits: potatoes
0	Not seen on field	Not seen on field
<0·1	1 in 7 yards radius	1 in 12 yards radius
<1·0	1 in 2 yards radius	1 in 4 yards radius

If more than 1 % is estimated counts to be made.

Apple Scab. The categories given apply to vigorous bush trees ten to fifteen years old which in July normally bear 10–15,000 leaves per tree, and they must be modified proportionately for trees of other, widely different sizes. Cox's Orange Pippin, Worcester Pearmain or Bramley's Seedling should be chosen wherever possible. At least twenty-five and preferably fifty trees of any one variety, evenly distributed through the plantation, should be graded visually by walking slowly around each tree. Individual tree grades should be recorded as well as the average, but if the first five trees all fall in or below category < 1·0 further individual grading is unnecessary. Trees too large to give a satisfactory single symbol can be graded and recorded separately from the four sides (N., S., E., W.). Sampling to be done preferably in July.

Category %*	Limits
0	No Scab seen
< 0·2	Up to 20 leaves scabbed. Very light infection
< 1·0	20–100 leaves scabbed. Light infection
< 5·0	100–500 scabbed leaves readily seen. Moderate infection
<25·0	500–2500 scabbed leaves. Healthy foliage still easily predominant. Severe infection
>25·0	Above 2500 leaves scabbed. Scabbed foliage apparently predominant, but may in fact be no more than 50 %. Very severe infection

* The severity on individual leaves will normally increase with the grades.

Descriptive notes about age, rootstock, grass or cultivated plantations, spray treatment, etc., are also required.

In addition to testing the above sampling methods, each collaborator is invited to make visual estimates on the same crops. By this means it should be possible to determine to what extent purely visual estimates are reliable. Finally, it is hoped that the occasion of the Society's 1942 Plant Pathology Field Meeting will afford an opportunity for comparing estimates made on the same crop by different observers.

REFERENCES

BAWDEN, F. C. (1941). Report of sub-committee on plant disease measurement in the field. *Trans. Brit. myc. Soc.* XXV, 218.

HORSFALL, J. G. & HEUBERGER, J. W. (1942). Measuring magnitude of a defoliation disease of tomatoes. *Phytopathology*, XXXII, 226–32.

TEHON, L. R. & STOUT, G. L. (1930). Epidemic diseases of fruit trees in Illinois 1922–1928. *Bull. Ill. Dep. Registr. & Educ., Div. Nat. Hist. Survey*, XVII, Art. 3, 415–502.

(*Accepted for publication* 30 *June* 1942)

AGARICS. NEW RECORDS AND OBSERVATIONS. II.

By A. A. PEARSON, F.L.S.

Most of the species referred to in the following notes are new records for the British Isles. Some are already in our books and are included only because I am able to add some further details to the descriptions:

Lepiota fusca-vinacea Möller & Lange, in Lange, *Flora Agaricina Danica* 1, 33, Pl. 13, fig. H (1935).

Pileus up to $4\frac{1}{2}$ cm., flat with shallow umbo, cuticle with concentric rings of dark adpressed squamules except at the disc, the surface between being purplish pink (pale vinaceous); margin smooth and regular sometimes stretching beyond the gills. *Gills* crowded, with a few small ones, thin, linear or somewhat ventricose, 3–4 mm. wide, free. *Stem* 5–6 cm. long, 5–8 mm. thick, firm, solid, purplish pink like the pileus, fibrillose above the white membraneous ring, densely tomentose below. *Flesh* of pileus and stem white with slight purplish tinge. No taste or smell. *Spores* white in mass, $4–4\frac{1}{2} \times 2–2\frac{1}{2}\mu$, smooth. *Cystidia* on gill edge club-shaped 25–35μ long by 8–12μ wide.

Habitat on ground in mixed woods. Found at Kinlet Park, Shropshire, by Miss Sheila Patrick during the foray held at Ludlow, September 1937.

Pholiota aurea Fr.

A fine group of this species in various stages of growth, some very large, appeared on the ground in a timber yard at Haslemere, during October 1938, and the opportunity was taken to add a few details to the descriptions in our books.

Pileus 4–25 cm., fleshy, convex then expanding and finally slightly depressed in centre with mat powdery surface at first, then like soft leather, dry and smooth, with here and there radiating grooves, Chamois colour of Ridgway, cuticle peeling to centre; margin incurved at first. *Gills* 12 mm. wide in large specimens, crowded, linear or arcuate, attenuated both ends, adnexed, adnate or subdecurrent edge often undulate, tawny ochraceous, of different lengths. *Stem* 10–27 cm. long, solid at first, thickened at base, up to 25 mm. diam. above ring, pale at first, then golden ferruginous covered with a white pruinose film. *Ring* peronate, sheathing most of the stem and splayed out above with an undulate margin; the outer part of sheath fluted with furrows deep above, shallow lower down, the ridges between being denticulate, covered with powdery granules above, smooth below, base with white tomentum. *Flesh* white in pileus and in upper part of stem, ochraceous buff in lower part, deeper in colour near surface. *Taste:* mild. *Smell:* nothing special noticed but said to be strong by some authors. *Basidia* four-spored 38–40 × 8–9μ. *Spores* in mass Clay colour of Ridgway, subfusoid, often with a large guttule 9–12 × $4\frac{1}{2}$–5μ.

Cystidia on gills not present. Surface of pileus with cells of different forms and sizes, mostly club- or sack-shaped, often with one or several finger-like appendages.

Pholiota aurea has been well illustrated in recent years by P. Heinemann in *Bull. Soc. Myc. Fr.* LIII, Atlas LXXV (1937), and by Lange in *Flora Agaricina Danica*, III, Pl. 105 C, the latter preferring to go back to the earlier name *Pholiota Vahlii* (Schum.). It may be doubted if the *Agaricus aureus* as described by Fries is the same, but his epithet for this species has been well established since it was described by R. Maire in *Bull. Soc. Myc. Fr.* XXVII, 438 (1911), with the suggestion that the powdery general veil and smooth spores were features justifying a new genus *Phaeolepiota*. This, however, has not found general acceptance.

Cooke's illustrations of this species have given rise to some confusion. The variety *Herefordensis* Renny on Pl. 374 (347) is the typical *Pholiota aurea* but too bright in colour; 373 (345) is probably *P. spectabilis*; 375 (348), wrongly named *P. caperata*, is certainly *P. aurea*, but there is a misprint in the spore dimensions which are given as $2 \times 4\frac{1}{2}\mu$ presumably instead of $12 \times 4\frac{1}{2}\mu$.

Clitocybe hirneola Fr.

Pileus 1–2 cm. submembranaceous, convex or umbilicate, lead colour or grey with a satin pruinose hoary white covering, which may be washed away in wet weather when it becomes clay-coloured or tawny olive with smooth surface, margin incurved then straight or undulate, sometimes striate. *Gills* crowded or subdistant, rather broad, adnate or subdecurrent, arcuate, pale clay or greyish, edge smooth or fimbriate. *Stem* 2–3 cm., slender, grey or clay colour, paler above, covered with white scattered fibrils or polished, equal or thicker above, sometimes with white tomentum at base. *Flesh* clay colour. *Smell* slightly mealy or none. *Taste* none or somewhat rancid. *Basidia* two- to four-spored $20–25 \times 6–8\mu$ with long sterigmata about 4μ. *Spores* in mass pinkish clay (Avellaneous of Ridgway), hyaline or very faintly coloured under the microscope, broadly ovate, with indistinct lateral apiculus, smooth, $6–8 \times 4\frac{1}{2}–5\mu$ non-amyloid. *Cystidia* on gill edge cylindrical or bottle-shaped with blunt apex, thin walled, $40–50 \times 10–12\mu$. Cuticle of pileus made up of septate hyphae $3–6\mu$ diam.

Habitat: on bare soil among heather and bracken especially where heath fires have taken place, isolated or in troops. Ludshott Common, Hampshire, November 1939 and 1940. Hindhead, Surrey, November 1940.

This agaric, which was abundant in 1939, has appeared only sporadically since, but is probably fairly common in the late autumn. Its distinctive features are the leaden hoary surface of the cap and the coloured spores. It is apt to be overlooked, as most specimens are small, semi-globate or with only slightly depressed cap. The larger specimens are sometimes deeply umbilicate. In fact, *Clitocybe hirneola* is a very variable fungus which may be recorded under other names and in other genera. It is very near *Tricholoma caelatum* Fr. which is described in great detail by Maire in *Bull. Soc. Myc. Fr.* XL, 298, and has verrucose spores, but it may be that this is part of the variability of this species. The spores of the specimens above

described were smooth when examined under an oil immersion lens. Doubtless it is often recorded as *Clitocybe rivulosa* which also has a satiny surface but differs in its small white spores and absence of cystidia.

Collybia misera Fr. sensu Lange. 'Studies in the Agarics of Denmark. III', *Dansk Bot. Ark.* II, no. 7, 20 (1917); *Flora Agaricina Danica*, II, 16, Pl. 45, fig. A (1936).

Pileus 1–2 cm., plano-convex, papillate, greyish umber with paler margin, strongly striate to umbo, edge regular, smooth. *Gills* broadly ventricose, fairly crowded, adnate or almost free, pale grey or dirty white, edge smooth, many lengths. *Stem* slender, 2–4 cm. long, dark grey, polished, pruinose above. *Flesh* dark grey when moist. *Smell* faint, rather rancid. *Basidia* four-spored. *Spores* white in mass, non-amyloid, narrow elliptic, smooth, 6–7 × 3½ μ. *Cystidia* none. *Cuticle* of pileus made up of elongated hyphae of different diameters, some sack-shaped and very bright under the microscope.

Habitat: gathered at edge of mixed wood, Thursley, Surrey, 6 November 1940.

It is doubtful whether this agaric is the *Agaricus miser* of Fries which has been variously interpreted by different authors. It is well illustrated by Lange and can be recorded under the name he assigned to it, until the *Tetrophanae* section of *Collybia* has been more thoroughly worked out.

Mycena uracea Pearson.

To the original description, *Trans. Brit. mycol. Soc.* XXII, 32–3 (1938), should be added 'spores amyloid'. As in all species of *Mycena* with warted cystidia, the spores turn blue with iodine.

Since this species was recorded, R. Kühner's Monograph of the genus *Mycena* has been published, and he describes, under the name of *M. megaspora* Kauffman, an American species which may be identical with *M. uracea*. The habitat is different; *M. megaspora* is found on bare peaty soil, while *M. uracea* appears on burnt ground attached to the roots of heather.

R. Singer has also recorded a similar species under the name of *M. permixta* (Britz.) Sacc. in *Rev. de Mycol.* II, 233 (1937). The habitat is said to be among *Sphagnum*.

Until further observations are made, *Mycena uracea* can stand. It is a common species in the late autumn, and I have gathered it in various places always on land where the heather has been burnt.

Photographs of *Mycena megaspora* Kauffman have since been sent to me by Mr Alex. H. Smith, who considers that this species is distinct from *M. uracea*.

Mycena mirata (Peck) sensu Smith, 'Studies in the Genus Mycena. I', *Amer. J. Bot.* XXII, 866, Pl. 3 (1935). Peck, *Bull. Buffalo Soc. Nat. Sci.* I, 48 (1873). Schroeter, *Die Pilze Schlesiens*, as *Agaricus* (*Mycena*) *corticola* Pers. p. 630 (1889). R. Kühner, *Le Genre Mycena*, p. 282 (1938).

Pileus 2–10 mm., membranaceous, semi-globate or subumbonate, sometimes with a papilla, whitish, pale brown at the disk, slight olive tinge when dry, striate or sulcate to disc. *Gills* subdistant, fairly broad, ventricose,

adnexed or free, cream, edge white, smooth or minutely fimbriate. *Stem* filiform, smooth, polished, grey, paler above, slightly swollen below, base sometimes hairy. *Smell* none. *Basidia* four-spored. *Spores* amyloid, elliptic apiculate with granular contents 8–9 × 5½–6 μ. *Cystidia* closely packed on gill edge, globose or sack-shaped, set with brush-like ornamentation. *Cuticle* of pileus with hyphae which turn blue with iodine, some being faintly warted.

Habitat: on bark of living trees, often among moss.

The specimens described above were on bark of oak and agree with Kühner's description except that the basidia had four sterigmata instead of two, and the spore range was smaller, which would be expected if two-spored basidia were absent.

Mycena mirata has some resemblance to *M. hiemalis* and a similar habitat, so it has probably been passed over as a form of this common species. The latter, however, differs in having non-amyloid spores and cylindrical smooth cystidia. Nearly related species like *M. supina* Fr. and pale forms of *M. corticola* Fr. have warted cystidia, but both have globose spores.

Mycena fellea Lange, 'Studies in the Agarics of Denmark. I', *Dansk Bot. Ark.* I, no. 5, 26 (1914). *Flora Agaricina Danica*, II, 37, Pl. 50.
? *Mycena erubescens* Von Höhnel, *Fragm.* XV, in *Sitz. K. Akad. Wiss. Wien*, Math.-Nat. Kl. I, LXXII, 267 (1913).

Pileus 3–10 mm. conical or semi-globate, dull grey or brown, with pale pruinose margin, striate. *Gills* subdistant, white, linear or slightly ventricose adnexed, broadly emarginate, two lengths. *Stem* 2–4 cm. long, slender, equal, hyaline or subfuscous, smooth, tomentose at base, sometimes when young with a whitish juice. *Taste* very bitter, not at first but like quinine after a while. No smell. *Basidia* 30–35 × 7½–8 μ with two long sterigmata. *Spores* amyloid, broadly ovate apiculate or pyriform with granular contents, one- to two-guttulate, 9–12 × 6–8 μ, smooth. *Cystidia* ventricose lanceolate often bifurcate, sometimes having several prongs, contents granular, abundantly scattered on gill edge and face, protruding conspicuously, 40–70 × 9–12 μ.

Habitat: usually on mossy trunks of deciduous trees, but the specimens described above were gathered at Goodwood, Sussex, on the ground under *Quercus Ilex* among moss and chips of wood, 15 November 1939. Rare in Great Britain but common in France and rather rare in Denmark.

In *Le Genre Mycena*, pp. 230–5 R. Kühner describes this species under *Mycena erubescens* V. Höhn., but neither in my specimens nor in those gathered by Lange did there occur any exudation from the pileus when cut nor any reddish coloration. It may well be that the two species are identical, the erubescent form being met with in southern climates. For the present it is preferable to use Lange's specific epithet which indicates a character not mentioned by Von Höhnel in his brief diagnosis. Kühner's specimens had basidia with two, three or four sterigmata.

Among my old notes of unnamed species of *Mycena* I find a drawing and full details of the above, found 26 November 1918 at St George's Hill, Surrey.

Mycena bulbosa (Cejp) Kühner, *Le Genre Mycena*, p. 176 (1938). *Pseudomycena bulbosa* Cejp, *Revise Omphalia-Mycena*, p. 149 (1930).

Pileus 3–6 mm., membranaceous, semiglobate, obtuse or subpapillate, striate or sulcate, greyish brown at first, then paler, hygrophanous, smooth, with gelatinous separable cuticle. *Gills* crowded, ventricose, adnexed becoming free, white or pale grey, alternate gills very short. *Stem* 4–10 mm. long, filiform, often curved, white hyaline or greyish brown, pulverulent *sub lente* with a basal disk 1–1½ mm. which is convex, pubescent, white and striate-sulcate on upper surface. A brown sclerotium is sometimes present hidden in the leaves from which the fruit body arises. *Taste* mild. *Smell* none. *Basidia* with four sterigmata. *Spores* non-amyloid, elliptical, 8–10 × 3½–4½ μ. *Cystidia* on gill edge only, ventricose or club-shaped, often bifurcated with several prongs. *Cuticle* of pileus with globose or pyriform cells, surface minutely granulate.

Habitat: at the base of tufts of rushes or more rarely of sedges. Found in various places in Sussex, Norfolk and Epping Forest.

This *Mycena* is common inside the tufts of rushes near the leaf base. In this sheltered situation the minute fruit bodies can be seen when the rushes are spread out. I recorded it for Epping Forest some years ago, but have since felt some doubts whether it is really distinct from *M. stylobates* which it closely resembles except that its more gelatinous nature makes it difficult to study and there are no spines on the pileus. Both belong to the section *Insititicia* which Kühner established for the species of *Mycena* having the pileus flesh distinct from that of the stem. In species of this section the hyphae of pileus and stem do not curve into each other, but are respectively horizontal and vertical, so that the pileus easily drops off the stem. But the spores of *M. bulbosa*, unlike all the other known species of this section, do not colour blue with iodine.

Mycena subalpina Von Höhnel, *Fragm.* XV, in *Sitz. K. Akad. Wiss. Wien*, Math.-Nat. Kl. I, CXXII, 21 (1913); Kühner, *Le Genre Mycena*, p. 543 (1938). *Collybia pseudo-radicata* Lange & Möller, *Friesia*, XV, 294 (1936); *Flora Agaricina Danica*, II, 13, Pl. 43, fig. A (1936).

Pileus conical or flat 1½–3 cm., membranaceous, dull brownish yellow or pale honey colour, mat, faintly striate or not at all, margin sometimes slightly exceeding gills. *Gills* subdistant, white, ventricose, rather broad, adnexed emarginate, edge rather shaggy, undulate. *Stem* 4–6 cm. long, 2½–3 mm. thick, somewhat cartilaginous, white, pruinose above, more or less striate, woolly at base. No smell or taste. *Basidia* with four sterigmata. *Spores* non-amyloid, white, cylindrical, slightly curved, 7½–10 × 2½–4 μ (mostly 8 × 3½ μ in my specimens). *Cystidia* on gill edge and face, flask-shaped with obtuse apex, smooth, 60–65 × 15 μ at base and 5–6½ above.

Habitat: solitary on sticks or chips in deciduous woods especially beech. In mixed wood Donhead St Mary, Wiltshire, 17 July 1939. Collected by A. Dunston, and recorded in *Wilts. Arch. and Nat. Hist. Mag.* XLIX, 150 (1940).

Mycena subalpina is uncommon, but may have been passed over as a form of *M. galericulata* which it resembles in some respects. The microscopic

characters are quite different and the spores of the latter turn blue with iodine.

Cooke's illustration 198 (205) of *Collybia collina* probably represents the above species.

Omphalia rosella J. E. Lange, 'Studies in the Agarics of Denmark. VIII', *Dansk Bot. Ark.* VI, no. 5, 14 (1930); *Flora Agaricina Danica*, II, Pl. 60, fig. C (1936).

Pileus submembranaceous, 5–15 mm., pale buff or brownish pink, mat, somewhat furfuraceous, depressed or deeply infundibuliform, margin plicate, incurved at first. *Gills* pale pink, arcuate, narrow, subdistant, rather thick, deeply decurrent, edge concolorous or sometimes darker, mostly one length with a few short ones. *Stem* relatively stout, 1–2 cm. long, 1–2 mm. thick, white or slightly pink tinged, naked or with fine white fibrils, equal or slightly thickened at the base. No taste or smell. Whole plant fairly firm and elastic. *Basidia* four-spored. *Spores* white in mass, non-amyloid, elliptical, flattened on one side, apiculate, smooth, $7\frac{1}{2}$–9×4–$4\frac{1}{2}\mu$, one- to two-guttulate in dropped spores. *Cystidia* scattered on edge of gill, cylindrical, 4μ diam., in projecting part, thickened at base.

Habitat: in short grass. Hindhead, Surrey, 20–27 October 1941.

This attractive *Omphalia*, which may be common as it appeared in quantities on my tennis lawn, has doubtless been confused with *O. demissa* Fr., which has a more striking resemblance to *Laccaria laccata*, grows in woods and has larger spores and no cystidia. *Omphalia demissa*, however, is not so well defined as we should like. Lange's measurements of the spores are much the same as for his *O. rosella*. Some years ago I had some specimens and measured the spores as 10–12×6–7μ. Bresadola and also Cejp in his monograph of *Omphalia* give 10–12×6–8μ. On Culbin Sands, Moray Firth, Scotland, I gathered specimens of an agaric growing on sand looking remarkably like *Laccaria laccata* but with smooth guttulate spores measuring 16–18×6–8μ which may be a form of *Omphalia demissa* Fr.

Marasmius lupuletorum (Weinm.) Bresadola, *Fungi Trident.* II, 24, Pl. 130 (1892); *Ic. myc.* Pl. 495 (1929). *Agaricus dryophilus* var. *lupuletorum* Weinmann, *Hym. et Gasterom. Rossiae*, I, 76 (1836); Konrad & Maublanc, *Icon. selectae fungorum*, Pl. 218.

Pileus $1\frac{1}{2}$–$3\frac{1}{2}$ cm., convex then flat, subumbonate, light buff darker in centre, cuticle adnate, dry, smooth, glabrous, margin thin, striate or sulcate, regular or undulate. *Gills* distant, adnexed then free, deeply ventricose, light buff, sometimes interveined, of several lengths. *Stem* $1\frac{1}{2}$–8 cm. long, cartilaginous, attenuated below, bay brown, paler above, velvety pruinose, base strigose. *Flesh* in pileus whitish, in stem light buff, sometimes bay brown or darker below. *Spores* non-amyloid, elongate pip-shaped, 7–9×4–5μ. *Cystidia* absent on gills, present on stem in bunches, brown, fusiform 30–60×4–6μ.

Habitat: in frondose and coniferous woods. Found in Wiltshire by T. F. G. W. Dunston and A. E. A. Dunston, October 1938, and recorded in the *Wilts. Arch. and Nat. Hist. Mag.* XLVIII, 484.

An uncommon species which may have been confused with the more common agaric which is recorded either as *Marasmius erythropus* (Pers.) Fr. or *Collybia acervata* Fr. and which has a much brighter coloured stem and smaller spores.

Russula brunneo-violacea R. Crawshay, *Spore Ornamentation of the Russulas*, p. 90, Pl. IX (1930). *R. purpurea* Gill., Cooke's *Ill. of Br. Fungi*, Pl. 986 (1022), cited by Crawshay. *R. pseudo-violacea* Joachim, *Bull. Soc. Myc. Fr.* XLVII, 256, Pl. VIII.

Pileus 3–10 cm., semiglobate then plane or depressed, at first violet-black, later violet or violet-brown or violaceous purple, often very dark in centre, occasionally with patches of yellow or rusty colour; exceptionally the whole surface may be mottled with yellow and dusky violet; mat, viscid when wet, margin smooth, sometimes sulcate, blunt. *Gills* rounded near margin of pileus, attenuated towards stem, adnexed or free or subdecurrent, white then cream, crowded, brittle. *Stem* 3–5 cm. long, 8–12 mm. thick, equal or slightly enlarged at base, at first firm, finally soft; white, turning brown in patches when handled. *Flesh* white or faintly yellow under the cuticle which is easily peeled. *Taste* mild. *Smell* none. *Spores* in mass cream (B to D of Crawshay's chart) somewhat variable, subglobose with long spines when examined under high magnification, finely reticulate, mostly $8\frac{1}{2}$–$7\frac{1}{2}\mu$. J. Schaeffer in his Monograph gives $8–10 \times 7–9\mu$ and Crawshay, who gives an accurate drawing of the spores, describes them as follows: 'Average measurement $8\frac{1}{2} \times 9\frac{1}{2}\mu$. The surface is covered with conspicuous protuberances which are rather above the usual size; in a certain number of spores the protuberances are unconnected, but in the majority they are connected by extremely thin lines which form a reticulation over a large part of the surface. Many of these spores possess an unusually large apiculus.' *Cystidia* abundant on gill edge, sparse on face, turning blue with sulphovanillin.

Habitat: in deciduous woods. Crawshay and Schaeffer record only from oak woods; Joachim under beech. My specimens were growing under or near birch in Rothiemurchus Forest and Kingussie, Scotland, August 1939. Also found in mixed wood of oak and birch at Hindhead, Surrey, August 1941.

This species, which is normally very dark violet colour, may prove to be fairly common. It is more slender than *Russula atropurpurea* which has white spores, and other Russulas nearest in colour and build are acrid. *R. violacea* Quél. is stated by Rea to be common, but I have never seen it in Britain; the strong smell of laudanum is characteristic, as I was able to verify when it was gathered in France.

Lactarius helvus Fr. is not well known to British mycologists and perhaps Cooke's plate 955 (994), which in colour is not in the least like the agaric it represents, is partly to be blamed for this. I have often gathered it, and the following description is taken from specimens which were growing under pine trees in Broadwater Forest, East Sussex, August 1936. *Lactarius helvus* was very plentiful that year, but I have not seen it in quantities since.

Pileus 4–20 cm. diam., depressed in centre, more or less infundibuliform, often with acute papilla, margin incurved when young, sometimes undulate

when old, not striate, felty with minute squamules, light pinkish cinnamon or very milky coffee colour, not zoned. *Gills* crowded, linear attenuated at both ends, about 5 mm. wide, decurrent or subdecurrent, forked from base, thin, edge smooth, cinnamon buff, small gills near margin. *Stem* 3–6 cm. long, 1–1½ cm. thick, cylindrical, often attenuated at base, straight or curved, firm when young, brittle when old, solid then hollow, dry, minutely fibrillose almost smooth, rather more reddish than pileus, base white tomentose. *Flesh* pallid with faint cinnamon tinge. *Milk* colourless watery not issuing except when young, mild, or very slightly acrid. *Smell* hardly perceptible when fresh, but pungently aromatic when dry like *Lactarius camphoratus*. *Basidia* four-spored. *Spores* in mass pale cream colour, broadly ovate, outline coarsely warted, covered with fairly thick reticulation when seen under high magnification, 7–9 × 5½–6μ. *Cystidia* on and near gill edge, cylindrical or slightly ventricose, blunt, not turning blue with sulphovanillin. No cystidia on pileus or stem. *Flesh* turns purple with Sv. and has no colour reaction from green vitriol or phenol.

Habitat: in moist coniferous woods.

Not considered a good edible, but *fide* Konrad and Favre, *Bull. Soc. Myc. Fr.* LI, 145 (1933), it is used when dry as a condiment in powder form.

L. helvus has been recorded in America as *L. aquifluus* Peck.

Cortinarius (Telamonia) malachius (Fr.), *Epicrisis*, p. 280 (1836); *Monographia*, 2nd ed., p. 361 (1874).

Pileus 4–15 cm., semi-globose at first, gibbous when expanded, fleshy, firm when young then soft; hoary ochraceous buff, then reddish buff often with reddish spots, tomentose *sub lente*; veil pale azure or lavender colour, then white adhering in small tufts or larger adnate patches near the margin; margin incurved at first and often when old, regular then undulate; cuticle dry, separable at margin sometimes to disk, radially cracking when old. *Gills* sub-crowded, broadly linear, pointed at margin, adnate with narrow emargination 6–10 mm. wide, not veined, edge more or less wavy, purplish blue before veil breaks, but when exposed to air instantly turning to purplish brown and finally to tawny brown. *Stem* cylindrical above, irregularly bulbous below, 10–14 cm. long, 1–2½ cm. thick, in large specimens with less bulbous base, firm when young, spongy when older, pale lavender-blue veil peronate below, often with adnate ring above and sometimes with other shaggy remains of veil which turns white with age and sometimes disappears leaving the stem naked. The base is often densely covered with a pale lavender-coloured tomentum, which is white when old. The bluish lavender tinge suffusing the stem is usually persistent but sometimes absent in old specimens. *Flesh* pale lavender-blue when young, then whitish and finally ochraceous buff. *Taste* mild. *Smell* not unpleasant. *Basidia* four-spored, with long sterigmata. *Spores* in mass light brown (Antique brown of Ridgway), surface smooth 7 × 4μ. *Cystidia* none, but some large sack-shaped cells of different sizes were observed on the gill edge. *Veil* made up of hyaline septate hyphae 6–8μ wide with occasional clamp connexions.

Habitat: in mixed woods. Our specimens were growing on sandy soil, under oaks, among bracken, near some young pine trees. Hindhead, early September 1941.

The above description taken from a number of specimens in all stages of growth, that appeared during a week, corresponds closely to that given by Fries in *Monographia*. Mr Carleton Rea, to whom specimens were sent, agrees. The spore measurements differ from those given by Quélet and by Lange, but I have no hesitation in determining our specimens as *Cortinarius malachius* Fr. Though the stem characters are clearly those of a *Telamonia*, it was placed by Fries in the *Inoloma* section on account of its hoary pileus. This character, however, is present in other species of the *Telamonia* group and its more correct position is next to *Cortinarius torvus* Fr. The bluish colour of the gills can be observed only when unexpanded specimens are freshly gathered, as the colour instantly changes when exposed to the air.

Cortinarius (Telamonia) helvelloides Fr.

As this species is not well known, though it sometimes appears in large troops in shady swampy places, a full description may be useful:

Pileus 1–4 cm. (mostly 2 cm.), fleshy in centre, membranaceous elsewhere, campanulate or conical at first, then flat or with shallow umbo, margin incurved and regular at first, finally upturned and undulate, dry, yellowish brown or dark ferruginous, brighter when dry with rusty gold centre, hoary with minute pale squamules, golden *sub lente* in a strong light. *Gills* distant, broadly linear, very variable in width, 3–7 mm., adnate with decurrent tooth, thick, dark violet at first, soon changing to dark brown, edge concolorous or paler, sometimes interveined in old specimens, in three lengths. *Stem* 4–8 cm. long, about 3 mm. thick, equal, firm, solid with an internal fibrous packing then hollow, rusty golden, reddish below, fibrillose with shaggy fragments of golden veil on the upper part of the stem forming a ring in young specimens, but usually absent. Base white strigose. *Flesh* brown in pileus, bright ferruginous in stem. No taste or smell. *Basidia* four-spored, 30–35 × 8–9 μ. *Spores* elliptic, apiculate, minutely punctate, $8\frac{1}{2}$–9 × 5–$5\frac{1}{4}$ μ. *Cystidia* absent. Elongated hairs 12–20 μ diam. on pileus. Hyphae with clamp connexions 8–10 μ wide on stem.

Fries in his description states that the gills are '*e violaceo—umbrino cinnameis*', but he placed this species in the group with gills yellow or cinnamon, not violet. Rea grouped it in the same section which made its determination difficult, but I am indebted to him for identifying specimens.

The above description was made from a large number of specimens gathered on 30 August 1936 which appeared for several years in a swamp under alders near Tunbridge Wells, Kent. Occasional specimens also grew on the edge of a ditch near Frant, Sussex.

The most prominent feature of *Cortinarius helvelloides* is the hoary squamulose pileus which shows up more distinctly when dry.

Alex. H. Smith has recorded this species from Michigan, U.S.A., under the name *C.* (*Dermocybe*) *lacorum* Smith in *Ann. Myc.* XXXII, 472 (1934).

I suspect that *C.* (*Inoloma*) *penicillatus* Fr. is the same species.

Cortinarius (Hydrocybe) rubricosus Fr. sensu Lange.

Pileus 5–7 cm., fleshy in centre, subconical at first, soon expanding, with prominent umbo usually blunt, sometimes acute, often depressed round umbo, reddish brown, paler at margin. Veil faintly evident on margin which is regular at first, but soon gets shaggy. *Gills* ventricose or broadly linear, 7–10 mm. wide, distant, concolorous, adnate becoming free, edge smooth. *Stem* solid then hollow, 6–8 cm. long, 8–10 mm. thick, concolorous, striate with pallid fibrils, equal or slightly attenuated at the base which is covered with a white pubescence. *Flesh* of pileus and stem brown. No smell or taste. *Basidia* four-spored. *Spores* in mass reddish brown (Amber Brown of Ridgway), broadly ovate, pip-shaped, warted, $8–9 \times 5\frac{1}{2}–6\mu$. *Cystidia* absent.

Habitat: on ground under *Pinus silvestris*, Thursley, Surrey, 4 November 1940.

The false ring mentioned by Fries was not seen in the specimens gathered, and it is not certain that we are dealing with the true *rubricosus* of Fries. Our specimens were clearly the same as illustrated by Lange in his *Flora Agaricina Danica*, Pl. 100, fig. F, and his interpretation of this rare species can be adopted for the present. Much work remains to be done before we can identify the puzzling members of the *Hydrocybe* group of *Cortinarius* with any certainty, more especially the smaller species. *C. rubricosus*, however, is of good size and can be distinguished by its umbonate cap and uniform date-brown colour.

Inocybe halophila Heim, *Le Genre Inocybe*, p. 242 (1931).

Pileus $1\frac{1}{2}–3$ cm. diam., umbonate or semi-globate, dark brown, shaggy and covered wholly or in part with a white arachnoid veil, fleshy in centre, membranaceous elsewhere. *Gills* deeply ventricose, free, brown with darker edge, often growing beyond margin of pileus. *Stem* rather short, equal or slightly thickened at the base, dark brown or pinkish, striate with whitish or yellowish fugacious fibrils. *Flesh* green in the pileus and apex of stem, brown in stem but paler at base. *Taste* mild. *Smell* not specially noticeable. *Basidia* four-spored. *Spores* in mass snuff-brown, cylindrical, narrowed to an obtuse point at the apex, broadly blunt at the base, straight or somewhat oblique, smooth, $10–14 \times 5–6\mu$ with large oblong guttule (full range *sec.* Heim, $9{\cdot}5 \times 20 \times 5–8\mu$). *Cystidia* on gill edge globose or sack-shaped at first, then flask-shaped with either broad or narrow neck, sometimes crested with lime crystals, hyaline or brown of various dimensions up to $90 \times 16\mu$ ($45–65 \times 11\frac{1}{2}–27\mu$, *sec.* Heim).

Habitat: in sea sand. Abundant in one small area on Culbin Sands, Moray Firth, Scotland, 19 August 1939.

Except for a few minor details, my specimens agree with Dr Heim's description, to whom I sent specimens for confirmation. The main difference is the persistent arachnoid veil which gave the group a very striking appearance. Heim says that the veil is fugacious. Mr Carleton Rea thinks this may be the species gathered on Culbin Sands in 1912 on the occasion of the B.M.S. foray, and named by him *Inocybe abjecta* Kant., which both

Lange and Heim identify with *I. flocculosa* Berk. It is doubtful, however, whether our species is really distinct from *I. lacera* Fr., one of our commonest species and very variable. The spore, which is so distinctive in this species, agrees exactly, but the macroscopic features are so unusual that there is some justification for separating the two species until we have some proof that *I. halophila* is merely a form due to its habitat in sea sand.

Astrosporina umboninota (Peck) n.comb. *Inocybe umboninota* Peck, *N.Y. State Mus.* CXXXIX, 58 (1910). *Inocybe acuta* Boud., *Bull. Soc. Myc. Fr.* XXXIII, 8, Pl. 1, fig. 2 (1917).

Pileus 1–4 cm., convex with a sharp prominent umbo, chestnut brown, darker in centre, umbo sometimes black, margin pale, radially fibrillose, more or less rimose, umbo smooth, margin incurved at first. *Gills* crowded, ventricose, pale then snuff colour, adnexed or free, sometimes minutely emarginate, edge delicately flocculose *sub lente*. *Stem* 2–5 cm. long, 2·3 mm. thick, solid, straight or curved, chestnut below, pale and pulverulent above, striate with fibrils, non-emarginate bulb at base not always well defined and white at first, then brown. *Flesh* white in pileus and stem at first, turning pale brown. No taste or smell. *Basidia* four-spored. *Spores* in mass snuff brown, nodulose 8–9 × 5½–6½ μ, profile irregularly elliptical or sub-triangular with nodules fairly prominent obtuse or acute. *Cystidia* on gill edge and face ventricose, neck not much narrowed, apex blunt, crested with crystals, hyaline, 50–70 × 15–20 μ.

Habitat: on the ground in boggy places, usually solitary. On bank of ditch in pine wood, Blackmoor, Hampshire, August 1937, and many other places since.

The species of *Astrosporina* with acute umbo run into each other rather closely. The above is nearly related to *A. napipes* (Lange) and is distinguished in the field by its short and slender stature.

Astrosporina Boltonii (Heim) n.comb. *Inocybe Boltonii* Heim, *Le Genre Inocybe*, p. 345 bis (1931). *Inocybe Rickenii* Heim non Kallenbach, *Le Genre Inocybe*, p. 346, Pl. XXXII.

Pileus 2½–5 cm., campanulate, gibbous or umbonate, rusty tawny then dark brown with adpressed radial fibrils, the disc often densely packed with short flat squamules. *Gills* crowded, fairly broad, ventricose, broadly adnate, edge smooth, pale at first then ferruginous brown. *Stem* 4–6 cm. long, 3½–5½ mm. thick, equal, striate with adpressed fibrils and some shaggy loose ones, pale brown or rusty below, pale and pruinose above, base white, solid then hollow. *Flesh* white or rusty brown in both pileus and stem. *Smell* none or slightly mealy. *Taste* mild. *Basidia* four-spored. *Spores* in mass snuff brown, irregularly angular with obtuse angles and prominent apical acute point; flattened below with no apiculus, 8–12 × 5–7 μ. *Cystidia* on gill edge and face, ventricose, obtuse, crested with crystals, thick walled at summit, hyaline, 30–55 × 18–21 μ. (Measurements of cystidia are those of Dr Heim, but specimens kindly identified by him had larger cystidia.)

Habitat: on sandy ground, solitary or in small groups, Epping Forest,

October 1935, sent by Mr R. E. B. Brinton. Also Henley, Sussex, November 1938.

In *Bull. Soc. Myc. Fr.* XLVIII, 147 (1932), Kühner has expressed some doubt whether *Inocybe Boltonii* Heim is distinct from *I. decipientiodes* Peck (=*globocystis* Vel.). They would seem to run into each other and their spores are very similar. In their typical forms, however, they are very distinct, and for the present it seems desirable to have a name by which we can identify an agaric which makes its appearance from time to time.

Galera Mairei (Kühner) n.comb. *Conocybe Mairei* Kühner, *Le Genre Galera*, p. 131 (1935).

Pileus 4–9 mm., convex or subconical, striate or sulcate at the margin, hygrophanous, light ochraceous buff, pulverulent with a greyish pruinous glistening *sub lente*. *Gills* concolorous then deeper in colour, thick, ventricose, subdistant, broadly adnate, sometimes exuding water-drops from edge. *Stem* short, equal or subbulbous, pale ochre above, darker below, delicately pulverulent below, hollow. *Basidia* four-spored. *Spores* elliptical, apiculate, smooth, $6\frac{1}{2}$–$7\frac{1}{2} \times 4$–$4\frac{1}{2}\mu$. *Cystidia* on gill edge abundant, 20–30μ long, thin walled, swollen below and narrowing to a long slender beak about 2μ wide. The cuticle of the pileus is made up of globose or balloon-shaped cells mixed with long beaked cystidia from which (see Kühner) exudes the moisture which produces the pruinose surface; similar cystidia occur on the stem.

Habitat: solitary or in groups in grassy places. Hindhead, 29 September 1938 near beech and holly.

This small *Galera* has the aspect of a small *Naucoria escharoides* but with strikingly granular pileus and ventricose gills.

The species of *Galera* with the cuticle of the pileus consisting of globose or hymeniform cells have been placed in a separate genus (*Conocybe* Fayod emend.) by Kühner, and those with elongated hyphae into another genus (*Galerina* Earle emend.). Although I do not follow Kühner in withdrawing such species from the genus *Galera*, I think the two segregates will prove useful as sectional headings in the grouping of *Galera* species.

Galera graminea Velenovský, *České Houby*, p. 548 (1921). *Galerina graminea* (Vel.) Kühner, *Le Genre Galera*, p. 168 (1935).

Pileus 5–10 mm., membranaceous, campanulate or shallowly conical, then flat with small umbo, finally upturned, hygrophanous, light ochraceous, margin pale and centre dark, finally whitish buff and sometimes furfuraceous, striate only when fresh. *Gills* subdistant of several lengths, thin, ventricose, adnate emarginate with decurrent tooth, but sometimes adnexed almost free with no decurrence, often veined near and on lower surface of pileus, light honey colour at first then ochraceous, edge smooth. *Stem* 2–$2\frac{1}{2}$ cm. long, about 1 mm. thick, pale honey colour covered with silky white striate fibrils, straight or flexuose, equal or slightly swollen at the base. No taste or smell. *Flesh* pale honey colour. *Basidia* mostly four-spored. *Spores* in mass ochraceous brown (Antique Brown of Ridgway), minutely punctate or smooth, 7–8 × 4–5μ (full range 7–11 × 4–$5\frac{1}{2}$), ellip-

tical or more or less obovate. *Cystidia* scattered on gill edge and sometimes on face, 20–40 μ long, bulbous below with a long slender neck, globose or oval at apex. *Cuticle* of pileus made up of elongated hyphae, 3–7 μ diam.

Habitat: on ground among moss. It appeared in large quantities scattered over my tennis lawn at Hindhead, Surrey, during October 1941, especially in the mossy places.

Galera nana (Petri) n.comb. *Naucoria nana* Petri, *N. Giorn. bot. it.* x, 357 (1903); *Ann. mycol.* II, 9 (1904). *Inocybe Whitei* Vel. non Berk. Br., *České Houby*, p. 371 (1920). *Galerula Velenovsky* Kühner, *Bull. Soc. Myc. Fr.* L, 72 (1934). *Galerina nana* (Petri) Kühner, *Le Genre Galera*, p. 219 (1935).

Pileus 4–25 mm., membranaceous, hygrophanous, slightly viscid, glabrous, fragile, conical or convex, umbonate or flat, sometimes papillate, striate, ochraceous brown with darker centre, pale when dry, margin regular or sometimes crenulate. *Gills* distant, thin, ochraceous, broad, ventricose or subtriangular, adnate or subdecurrent, emarginate. *Stem* 2–6 cm. long, equal, straight or flexuose, ochraceous, darker towards base, delicately pruinose above with adpressed fibrils below. *Flesh* ochraceous. *Taste* mild. *Smell* mealy, scarcely perceptible. *Basidia* with two sterigmata (sometimes three, see Kühner). *Spores* in mass brown (Brussels Brown of Ridgway), almond-shaped or subfusiform, surface with a shallow mottled ornamentation. *Cystidia* abundant and prominently projecting on gill edge and face, flask-shaped, thick walled with crested apex, staining sulphur yellow with ammonia and vinaceous purple with cresyl blue. *Cuticle* of pileus consisting of elongated hyphae $2\frac{1}{2}$–$3\frac{1}{2}$ μ diam.

Habitat: grassy places or naked soil. The typical small form I gathered in Ashdown Forest, Sussex, 17 October 1931, and Dallington, Sussex, 30 September 1934. A large form (pileus 1–$2\frac{1}{2}$ cm.) with a densely caespitose habit was growing luxuriantly on an old sawdust heap at Plaistow, Sussex, 15 November 1938.

This not uncommon agaric has probably been identified with *Naucoria badipes* Fr. It is chiefly characterized by the cystidia which are of the type associated with the genus *Inocybe*. There is, however, a difference; the *Inocybe* cystidia turn blue with cresyl blue, while those of *Galera nana* turn a vinaceous purple as pointed out by Kühner. This species was described by Velenovský under the name *Inocybe Whitei* Berk. & Br., but Cooke's Illustration, Pl. 444 (404), representing this last species is certainly quite different.

With regard to *Naucoria badipes* Fr., this epithet has been used for several different species, and it would be well to accept the definition of Ricken who assigns the species to *Galera* rather than to *Naucoria*, which is at present a convenient dumping ground for many small brown-spored agarics which have still to find their right taxonomic position. *G. badipes* (? Fr.) Ricken is very like *G. nana*; it has two-spored basidia, and spores of the same shape, but differs in the cystidia which are thin walled and without the crested apex. It is not uncommon in grassy places on the edge of woods.

Psathyra pennata Fr. forma ***annulata*** n.f.

Pileus 1–3 cm., membranaceous, convex or conical, then expanding with persistent blunt umbo, edge incurved, finally upturned but sometimes the margin remains involute, ochraceous, umbo darker, wrinkled in old specimens, at first covered with white fugacious scales. *Gills* subdistant, broad, ventricose, adnate, white at first then fuscous brown, edge smooth. *Stem* 3–4 cm., white, tomentose above the ring, delicately fibrillose below, ochraceous flesh seen underneath the fibrils, equal or thickened at the base, fairly firm in outer coat with a fibrous core; veil forming a well-defined white woolly ring half-way up the stem, fairly persistent. *Flesh* ochraceous, dark line between pileus and gills. No smell or taste. *Spores* in mass Blackish Brown of Ridgway, subcylindrical, flattened on one side, more or less pointed at one end, dark brown under microscope, $6\frac{1}{2}$–7×3–$3\frac{1}{2}\mu$. *Cystidia* on gill edge fusoid with acute apex, 35–45×10–12μ.

Habitat: in troops on burnt soil near pine stump, Hindhead, Surrey, October 1941.

This small agaric was growing in abundance within the space of a few yards, while in other parts of the same ground were troops of the normal form of *Psathyra pennata* or what we call by this name, as it is the common species that flourishes on burnt soil. It is, however, doubtful if it is the same as recorded elsewhere. The British species invariably has small subcylindrical spores about $7 \times 3\mu$, but continental mycologists give the following measurements: Bresadola 8–9×4–$4\frac{1}{2}$, Ricken 8–9×5–6, Lange 8–$9\frac{1}{2} \times 4\frac{1}{2}\mu$.

The ringed form of *P. pennata* may have been recorded as a *Stropharia*, but no species in this genus seems to correspond.

Cooke's Plate 620 (580) of *Psathyra pennata* is fairly good except that unusually large specimens have been figured, and the patches of the white veil which are often very conspicuous in separate but very fugacious squamules near the margin of the pileus, are not shown; but this is a very variable feature.

(*Accepted for publication* 4 *July* 1942)

GLOEOSPORIUM PESTIFERUM, A SYNONYM OF *ELSINOE AMPELINA*

By ANNA E. JENKINS, *Bureau of Plant Industry, Washington, D.C.*

(With Plate IV)

Gloeosporium pestiferum Cke. & Mass. (1890) is based upon specimens of infected 'twigs, peduncles, and fruit of *Vitis vinifera*' from 'Brisbane (F. M. Bailey 881)'. Cooke (1890) noted that this organism was 'very destructive to vines'. Writing of it in the *Gardeners' Chronicle* (1891) he stated: 'In some respects the fungus resembles another of the same genus (*Gloeosporium ampelophagum*) common on vines in Europe and the United States; but it differs in the colour of the exuded spore masses, and the dimensions of the spores, which are double the length, and broader than in the European species; besides which we have no knowledge that the mass of spores in *Gloeosporium ampelophagum* ooze out and form such *Tubercularia*-like masses.' The note closes with the statement that the organism 'is an unenviable addition to the fungi of Australia'. *Gloeosporium ampelophagum* (Pass.) Sacc. is, of course, the grape anthracnose organism, which was earlier described as *Sphaceloma ampelinum* de By., and which is now known in its perfect stage as *Elsinoe ampelina* (de By.) Shear (1929).

Through Mr J. H. Simmonds of the Department of Agriculture and Stock, Brisbane, Queensland, with whom I have been in correspondence, the previously noted specimen, F. M. Bailey 881, in the Herbarium of the Government Botanist, Brisbane, was lent for examination by Mr C. T. White, Government Botanist.

The specimen, according to the label, is from grapes grown at Rockhampton, Queensland. It consists of a single shoot about 2 in. long, together with a few leaf fragments. The cankers on the heavily infected stem are typical of grape anthracnose. Sections through one of them showed abundant acervuli of *Elsinoe ampelina*. There was also seen a single biguttulate conidium, $6 \times 4 \mu$, evidently of this fungus. This conidial stage is probably the imperfect fungus that Cooke described as *Gloeosporium pestiferum*. The unusually large spores that he described apparently were swollen, as illustrated by Cobb (1903, fig. 111, compare with fig. 112) in a fungus now known to be related to the grape anthracnose organism, i.e. *Sphaceloma rosarum* (Pass.) Jenkins (1931). *G. pestiferum* as described by Cooke agrees in general with his illustration of *G. ampelophagum* (1893, fig. 10) and with such illustrations as those of earlier date by Scribner (1886, col. pl. 6 *a*, *b*). An illustration showing clearly the structure of the acervulus of *G. ampelophagum* was published in New South Wales by Cobb (1892, fig. 16). That author reproduced (1891 *b*) Cooke's second account (1891) on *G. pestiferum*, but made no comment on the identity of the fungus. He had written on grape anthracnose in New South Wales in 1891 (1891 *a*).

87398

In Shear's collection at Washington, D.C., there is a fragment of the original type of Bailey's specimen 881 from Cooke's herbarium at Kew. This consists of parts of stems and a few berries. A second specimen from the Cooke Herbarium, shown to me by Dr Shear, bears the label '*Gloeosporium pestiferum* Cke. & Mass. Melbourne 574'. On the label of this specimen Dr Shear has indicated that the original label on the specimen at Kew is in Cooke's own handwriting. Concerning the two specimens Shear has also noted that 'these show undoubted anthracnose'.

It seems to be fully established, then, that *Gloeosporium pestiferum* Cke. & Mass. is a synonym of *Elsinoe ampelina*. D. Saccardo (1898) identified a fungus on grape in Italy as *Gloeosporium pestiferum* Cke. & Mass., but he explained certain lack of agreement. Judging from his description and illustration (pl. 8, fig. 8) of the Italian fungus, this is entirely different. Melbourne 514 may have been Cooke's (1892) basis for the distribution of *G. pestiferum* in Victoria. There are no specimens of *G. pestiferum*, so named, in the National Herbarium at Melbourne, as has been ascertained through Mr S. Fish, Biologist of the Victorian Department of Agriculture. He wrote (December) that there is one undated specimen of *G. pestiferum* in the herbarium of the Department of Agriculture labelled in the handwriting of D. McAlpine, with the details 'On *Vitis vinifera*, leaf and twig, Queensland, contributor, Bailey (and Kiel?)'.

Mr Fish stated also that the earliest specimen of *Gloeosporium ampelophagum* in the Herbarium of the Victoria Department of Agriculture is on vine leaves from Western Australia, 21 November 1898, contributed by R. Helms, while the earliest Victorian specimen is from Linton, 9 February 1903, T. M. Wise. Cooke (1892) reported *G. ampelophagum* from Victoria in 1892, but gave no other distribution.

The first diagnosis as well as the earliest account of grape anthracnose in Australia appears to be that by Tryon (1889) or Cobb (1891*a*, 1892). Excerpts from the first paragraph of Tryon's report are made as follows:

'The vine disease known throughout Australia as Black Spot, was observed to be prevalent at Toowoomba at the time of our visit.... Black spot as a disease of the vine, was known in Australia as far back as 1862, if not at an earlier date, although we are not aware that its precise nature has ever been ascertained.... Those Toowoomba settlers who have made their early acquaintance with the vines in the Rhine Districts designate this disease as the *Schwarze Brenner*, a malady of the vines known to be caused by *Sphaceloma ampelinum*, and microscopic examination establishes the fact that this title which they have bestowed is the correct one, and that the Black Spot and Schwarze Brenner are one and the same disease, both being due to the presence of the above-mentioned fungus.'

REFERENCES

COBB, N. A. (1891 *a*). Anthracnose or 'Black spot' on grape vines. *Agric. Gaz. N.S.W.* II, 60–1.

COBB, N. A. (1891 *b*). Notes on diseases of Plants. *Agric. Gaz. N.S.W.* II, 348.

COBB, N. A. (1892). Diseases of the vine. Anthracnose or 'Black spot' (*Gloeosporium ampelophagum* Sacc.). *Agric. Gaz. N.S.W.* III, 291–2.

COBB, N. A. (1903). Diseases of the rose. Black Spot. *Agric. Gaz. N.S.W.* XIV, 1063–4.

COOKE, M. C. (1890). Australian fungi. *Grevillea*, XIX, 61.

COOKE, M. C. (1891). Another vine disease (*Gloeosporium pestiferum* C. & M.). *Gdnrs' Chron.* 17 Jan. pp. 82–3.

COOKE, M. C. (1892). *Handbook of Australian Fungi*, p. 363.

COOKE, M. C. (1893). Anthracnose of the vine. *Gdnrs' Chron.* 8 July, p. 33.

JENKINS, A. E. (1931). Rose anthracnose caused by *Sphaceloma*. *J. agric. Res.* XLV, 330.

SACCARDO, D. (1898). Contribuzione alla micologia veneta e modenese. *Malpighia*, XII, 216–17.

SCRIBNER, F. L. (1886). Report on the fungus diseases of the grape vine. *Bull. U.S. Div. Bot.* II, 34–8.

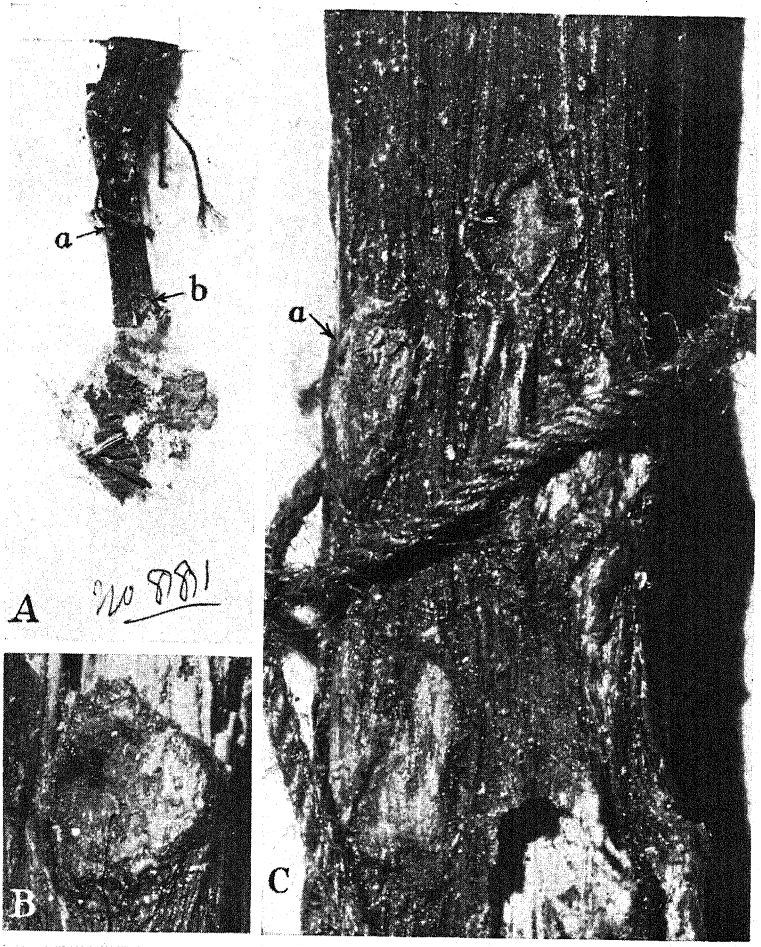
SHEAR, C. L. (1929). Life history of *Sphaceloma ampelinum* de By. *Phytopathology*, XIX, 677.

TRYON, H. (1889). Report on insect and fungus pests. *Rep. Qd Dep. Agric.* I, 165–8.

EXPLANATION OF PLATE IV

Gloeosporium pestiferum Cke. & Mass. on grape vines from Rockhampton, Queensland, Bailey 881. A, the entire specimen, natural size. B and C, lesions from A, enlarged 10 times. C, *a*, lesion shown in A, *a*; B, lesion shown in A, *b*. D, label of specimen in original handwriting.

(*Accepted for publication* 18 *July* 1942)



Gloeosporium
pestiferum, Ckeit Mass
on Gramineous Rockhampton

D

BRITISH NECTRIOIDEAE AND ALLIED GENERA

By T. PETCH

The formidable assemblage, Sphaeropsideae, which included fungi which looked like Sphaeriaceae but had their spores on sporophores instead of in asci, was divided by Saccardo into four groups, the first two being Sphaerioideae and Nectrioideae, the former having, as a rule, black or fuliginous, sometimes carbonaceous pycnidia like the perithecia of a *Sphaeria*, and the latter brightly coloured, soft or fleshy pycnidia like the perithecia of a *Nectria*. Roughly that corresponds to the division of the ascigerous forms into Sphaeriaceae and Hypocreaceae, and many of the Nectrioideae are stages of species of Hypocreaceae. The third volume of Saccardo's *Sylloge Fungorum* was based on that division and the system has now been in use for over fifty years, during which period numerous defects in Saccardo's arrangement, principally due to insufficient description on the part of the authors of the various genera and species, have become evident. The present account deals with the brightly coloured forms, Saccardo's Nectrioideae and part of his Excipulaceae.

Many of these pycnidial forms had been known for a long time as stages of Hypocreaceae, Discomycetes, etc., but in general it had not been considered necessary to give them separate names. Fuckel, for example, mentioned several, sometimes with a brief description. Saccardo bestowed names on these, and endeavoured to place them in their correct position relative to other pycnidial forms which had been named and described without association with any perfect form.

In the current century attempts have been made, particularly by von Höhnel, to correlate these forms and arrange them in a definite system, but, although von Höhnel examined type specimens whenever possible, much remains to be done before a satisfactory arrangement can be made. The original descriptions are often too brief to be of much service, and naturally they include only details which appeared to the describer to be of importance, whereas the systematist engaged in the classification of a number of forms may be compelled to adopt distinguishing characters, e.g. the position of the fungus in the host tissue, which the original describer did not consider worthy of record.

von Höhnel's chief communications are contained in the following articles and journals:

A. Zur Systematik der Sphaeropsideen und Melanconieen (Vorläufige Mitteilung), in *Annales Mycologici*, IX, 258–65 (1911).

B. System der Fungi Imperfecti, in Falck, *Mykologische Untersuchungen*, I, 301–69 (1923).

C. Fragmente zur Mykologie, nos. 1–1225, in *Sitzungsberichte der Akademie der Wissenschaften in Wien, Mathem.-naturw. Klasse*, Abt. I (1902–23).

D. Mykologisches, nos. 1–393 (24 parts), in *Österreichischen botanischen Zeitschrift* (1904–16).
E. Mykologische Fragmente, nos. 1–333 (14 parts), in *Annales Mycologici* (1903–20).
F. Fungi Imperfecti: Beiträge zur Kenntnis derselben, nos. 1–116 (3 parts), in *Hedwigia* (1917–20).
G. Vorläufige Mitteilung mykologischer Ergebnisse, 1–500 (5 parts), in *Berichte der Deutschen Botanischen Gesellschaft* (1917–19).
H. *Mitteilungen aus dem Botanischen Laboratorium* [later *Institut*] *der Technischen Hochschule in Wien*, I–XII (1924–35), published by Prof. Dr Josef Weese after von Höhnel's death.

These papers will be cited in the following pages by the letter prefixed to them. In 1911 (A) von Höhnel proposed the following division:

I. Pycnidiaceae.
  (*a*) Sphaerioideae.
    (α) Ostiolatae.
    (β) Astomae.
  (*b*) Nectrioideae.
    (α) Ostiolatae.
    (β) Astomae.
II. Patelloidaceae [later Patelloideae].
  (*a*) Excipulatae.
  (*b*) Patellatae.
III. Pycnothyriaceae.
IV. Stromaceae.

This account deals with the Nectrioideae-ostiolatae, Nectrioideae-astomae, and Patelloideae-patellatae, together with three genera of Stromaceae. The keys given are adapted from von Höhnel's key in his *System der Fungi Imperfecti*, abridged to include the small number of genera known to occur in this country.

von Höhnel's *System der Fungi Imperfecti* was published in 1923, but it had been sent to the editor in 1916, and publication had been delayed by war conditions. It would seem doubtful, therefore, whether the position of a genus in his *System* always represents his latest opinion, and it must be checked by reference to his later writings. The publication of these continued until his death in 1920, and notes which he left were afterwards published by Weese (H). Many of his later writings are merely preliminary lists of generic changes, and a formal description of the new genus does not appear always to have been published. Whether the new generic name is valid is a question for the nomenclatorial experts. In some instances, e.g. *Hyalopycnis*, the type of the genus is known, and the generic characters are given piecemeal in his key, but I have not found a formal description.

There would appear to be need for further investigation of several species included by von Höhnel in his pycnidial fungi to ascertain whether they actually have a pycnidium at any stage. *Ypsilonia cuspidata*, for example, placed by von Höhnel in Patelloideae-excipulatae, has a sporodochium surrounded by clusters of long setae which converge over it, but they are not united to one another above, and the fungus appears to be a hyphomycete. To illustrate the uncertainty which exists in some instances, *Microcera* may be cited. To some mycologists the sheath of *Microcera* is negligible, and the fungus is a *Fusarium*; to von Höhnel, the sheath constitutes a pycnidial wall, and the fungus belongs to the Patelloideae-

patellatae (G. no. 496, 1919; C. no. 1195, 1920). Actually the sheath divides above into laciniae and separate hyphae, and the fungus should be left in the Tubercularíae.

NECTRIOIDEAE

Pycnidia hyaline or light-coloured, membranous to fleshy, soft.

NECTRIOIDEAE-OSTIOLATAE

Pycnidia generally with a pre-indicated ostiolum.

I. Sporidia hyaline, oval, one-celled
  A. Pycnidia beaked or cylindrical, superficial
    (*a*) Sporidia with a cilium at each end — *Sphaeronaema* Fr.
    (*b*) Sporidia without cilia
      1. Pycnidia hyaline, of parallel broad hyphae: sporidia oval — *Hyalopycnis* v. Höhn.
      2. Pycnidia pyriform; sporidia small fusoid, acute — *Mycorhynchella* v. Höhn.
  B. Pycnidia not beaked
    (*a*) Immersed, becoming free — *Zythia* Fr.
    (*b*) Immersed, on an immersed stroma — *Zythiostroma* v. Höhn.
    (*c*) Superficial, blue or violet, parenchymatous — *Cyanophomella* v. Höhn.
    (*d*) Superficial, microplectenchymatous — *Pycnidiella* v. Höhn.

II. Sporidia oval, two-celled, hyaline or subhyaline
  A. Pycnidia superficial, light-coloured, not blue or violet — *Stylonectria* v. Höhn.

III. Sporidia hyaline, with several cross-septa
  A. Pycnidia superficial, blue or violet, large-celled parenchymatous — *Stagonostroma* Died. *Fusidomus* Grove

IV. Sporidia linear-fusoid, two-celled; pycnidia beaked, superficial — *Mycorhynchus* Sacc.

SPHAERONAEMA Fr. *Syst. Myc.* II, 535 (1823)

Type species, *Sphaeronaema subulatum* (Tode) Fr. *loc. cit.*

Pycnidia superficial, light-coloured, conoid, or flask-shaped, or subglobose with a short cylindrical or conical neck, wall membranous, parenchymatous, ostiolum fimbriate; sporophores stout, branched, sporidia apical and lateral; sporidia hyaline, continuous, oval, with a short pedicel and an apical seta.

SPHAERONAEMA SUBULATUM (Tode) Fr. *Syst. Myc.* II, 535 (1823); *Sphaeria subulata* Tode, *Fung. Mecklenb. Sel.* II, 44 (1791); *Sphaeronaema oxysporum* Berk. *Lond. J. Bot.* (1847), 325; *Sphaeronaemella oxyspora* (Berk.) Sacc. *Syll. Fung.* III, 618 (1884).

Pycnidia scattered or clustered, conoid, rounded at the base, up to 0·6 mm. high, 0·4 mm. diameter, or flask-shaped or subglobose with a

short conical or subcylindrical neck, hyaline, wall parenchymatous, ostiolum fimbriate; sporophores stout, 2–3 μ diameter at the base, closely septate, with numerous lateral branches attenuated at their apices; sporidia terminal, or lateral at the septa of the main stem, hyaline, continuous, oval or narrow oval, 5–9 × 1·5–2·5 μ, with a pedicel 2–4 μ long, and an apical seta 3–7 μ long.

On decaying agarics, *Boletus*, *Sparassis*. Edinburgh and Tarbet (Greville); Appin (Carmichael); Cambridge (Berkeley); Thirsk (*Fungus Flora Yorks.*); Llanymawddwy (A. L. Smith); Westwick, Norfolk (Petch).

Fuckel (*Symb. Myc.* p. 183) claimed to have found asci in specimens of *S. subulatum*, and founded a new pyrenomycetous genus, *Eleutheromyces*. His claim has been supported by numerous mycologists and rejected by others (see Petch, *J. Bot.* (1935) p. 186), but, even if correct, *Sphaeronaema subulatum* still remains the name of the pycnidial form. As no other similar fungus has been described, *Sphaeronaema* is, up to the present, a monotypic genus.

In *Sylloge Fungorum*, Saccardo omitted *Sphaeronaema subulatum* from the genus, and drew up a generic description which, while retaining the general shape of the pycnidia, described them as superficial or immersed, membranous, coriaceous, or carbonaceous. Consequently the genus has come to include species of *Micropera*, over-ripe *Ceratostoma*, long-necked *Phoma*, etc. His type species is *Sphaeronaema polymorphum* Auersw. *Bot. Zeit.* p. 181 (1851), which, *teste* von Höhnel in F. No. 34 (1917), is *Glutinium laevatum* (Fr.) Stärb., the type of Fries's genus *Glutinium*. For other species of *Sphaeronaema*, see von Höhnel, *loc. cit.*

Of the species of *Sphaeronaema* enumerated by Grove in *British Stem and Leaf Fungi*:

S. spurium Sacc. is *Micropera spuria* v. Höhn. C. No. 950 (1916).

S. versiforme Fr. is *Micropera versiformis* Grove, II, 361.

S. rostratum Fuckel is *Ceratophoma rostrata* (Fuckel) v. Höhn. F. No. 34 (1917).

S. floccosum Grove and *S. mirabile* Grove are probably *Ceratophoma*.

S. epimyces (Ehrenb.) Berk. is 'certainly not a *Sphaeronaema*' (Grove).

S. deformans Berk.; *Phyllosticta deformans* (Berk.) Jacz., 'might be *Phyllosticta*' (Grove).

S. Lycopersici Plowr. Grove places this in *Ascochyta* (I, 314), probably correctly. Plowright described and figured the spores as continuous, but, *teste* Grove, the spores of *A. Lycopersici* may remain in that condition for a long time.

S. aemulans B. & Br. The type requires redescription.

S. glomeratum Mont. No such species. Saccardo suggested that this was an error for *S. fasciculatum* Mont. & Fr.

S. cornutum Preuss. As redescribed by Grove, and figured by Miss M. E. M. Johnston in *Trans. Brit. myc. Soc.* v, pl. VI, this is not a *Sphaeronaema*.

HYALOPYCNIS von Höhn. D. no. 162 (1916), name only

Type species, *Hyalopycnis vitrea* (Corda) v. Höhn. D. no. 162 (1916) and F. no. 58 (1918).

Pycnidia superficial, light-coloured, membranous, globose with a long subcylindrical beak, fimbriate at the apex; wall of venter and beak composed of parallel hyphae fused laterally; sporophores long, simple or branched; sporidia hyaline, continuous, cylindrical or oval.

HYALOPYCNIS BLEPHARISTOMA (Berk.) v. Höhn. D. no. 162 (1916); *Sphaeronaema blepharistoma* Berk. *Mag. Zool. Bot.* I, 512 (1837); *Sphaeronaemella blepharistoma* (Berk.) Petch, *J. Bot.* p. 190 (1936).

Pycnidia superficial, globose, up to 0·3 mm. diameter, with a cylindrical beak up to 0·8 mm. high, 0·12 mm. diameter, fimbriate at the apex, hyaline; sporophores long; sporidia apical, hyaline, continuous, cylindrical with rounded ends, or oblong-oval, or oval, 8–13 × 3–5 μ, sometimes broadly apiculate.

On decaying *Russula adusta*, King's Cliffe (Berkeley); on the same host, North Wootton, May 1935.

Berkeley also recorded this species on nettle roots, and I have similar specimens on decaying stalks of *Brassica* and hollyhocks, but the latter have larger spores and are probably another species of *Hyalopycnis*. Berkeley's specimens on nettle, if any, have not been examined.

MYCORHYNCHELLA von Höhn. F. no. 59 (1918)

Type species, *Mycorhynchella exilis* v. Höhn. F. no. 59 (1918).

Pycnidia superficial, hyaline or bright-coloured, ovate, beaked, the venter small-celled plectenchymatous below, above (including the beak) of elongated parallel cells; sporophores simple; sporidia small, hyaline, cylindrico-fusoid, continuous, or longer and then septate.

MYCORHYNCHELLA GLOMERATA (Grove) Petch, comb.nov.; *Sphaeronaemella glomerata* Grove, *Brit. Stem and Leaf Fungi*, II, 116 (1937).

Pycnidia solitary, or in clusters of three to six, superficial, soft, ovoid with a beak-like ostiole, i.e. obpyriform, 200–300 μ diameter, pure rose-coloured, then rosy brownish, surrounded at the base by numerous delicate rosy intertwined hyphae; ostiolum fimbriate; sporidia very numerous, oval, obtuse, often somewhat curved, biguttulate, nearly colourless, 3–5 × 1·5 μ.

On a gelatine culture in a Petri dish, Birmingham (Grove).

ZYTHIA Fr. *Summa Veg. Scand.* p. 407 (1849)

Type species, *Zythia elegans* Fr. *Summa Veg. Scand.* p. 408 (1849).

Pycnidia immersed, becoming free, globose, with a more or less evident papilla; wall of small cells, waxy-fleshy, light-coloured, usually yellow, orange, or red; sporophores various; sporidia hyaline, continuous, linear, ovoid, or oblong. See von Höhnel, C. nos. 26 (1902) and 906 (1915).

ZYTHIA MERCURIALIS Kickx, *Flor. Crypt. Fland.* I, 449 (1867).

Pycnidia scattered or gregarious, dull yellow, then rust-coloured, finally brown and blackening, minute, almost globose, 100–125 μ diameter, with an ostiolum 25 μ diameter; sporidia ovate, usually about 5 × 2–2·5 μ, with a few almost double in length, occasionally one-septate and constricted at the septum, 10 × 3 μ.

On leaves, petioles, and stalks of *Mercurialis perennis*, Garforth, Yorks. (*Trans. Brit. myc. Soc.* VI, 79, 155); Lancashire (Grove).

The descriptions do not give any clue to the position of the pycnidia in the tissues, and specimens are not available at present. It is possible that this species is not *Zythia*, *sensu* von Höhnel.

ZYTHIA LEUCOCONIA (B. & Br.) Sacc. *Syll. Fung.* III, 615; *Sphaeronaema leucoconium* B. & Br. *Ann. Nat. Hist.* (2), V, 371 (1850).

Pycnidia gregarious on a white subiculum, minute, depressed, sub-hemispherical or irregular, with a few hyphae spreading from the sides, hyaline, pale brownish in old herbarium specimens, pierced by a round pore, without a papilliform or elongated ostiolum, texture minutely parenchymatous; sporidia hyaline, ellipsoid, obtuse at both ends or somewhat pointed below, 5–6 × 2–3 μ (Berkeley and Broome, and Grove).

On decaying roots of 'Silesian Beet', King's Cliffe (Berkeley), [? Sicilian Beet, *Beta Cicla*, Sugar Beet].

von Höhnel (C. No. 27) suggested that this species should be placed in *Libertiella* Speg. & Roum., which differs from *Zythia* only in the wider opening and consequent saucer shape of the pycnidia. The type requires redescription.

ZYTHIOSTROMA von Höhn. H. VIII, 89 (1931), emend.

Type species, *Zythiostroma Mougeotii* (Fr.) v. Höhn. H, VIII, 89 (1931).

Pycnidia subglobose, light-coloured, fleshy, soft, with a short cylindrical ostiolum, seated on a light-coloured fleshy stroma, but at first remaining immersed in the host; sporidia oval or oblong-oval, hyaline, continuous.

ZYTHIOSTROMA MOUGEOTII (Fr.) v. Höhn.; *Sphaeria Mougeotii* Fr. *Elenchus*, II, 100 (1828); *Sphaeronaemella Mougeotii* (Fr.) Sacc. *Syll. Fung.* III, 617 (1884).

Pycnidia subcortical, ostiolum erumpent, or exposed by abscission of the outer layers of the cortex, scattered, on an immersed, red, fleshy stroma, red, soft, subtranslucent, subglobose or conoid, 0·25–0·4 mm. diameter, ostiolum shortly cylindrical, dark red; sporophores fasciculate, short, simple or branched, the ultimate branches stout, conoid or somewhat flask-shaped; sporidia oblong-oval, hyaline, 2·5–3·5 × 1 μ.

The pycnidial stage of *Nectria sinopica* Fr. On dead stems of ivy, with the perithecial stage. North Wootton, October 1937, etc.; Mulgrave Woods, Yorks., October 1937 (W. G. Bramley).

The stroma and pycnidia may be exposed in cracks in the cortex, or may remain embedded, only the ostiola penetrating the cortex. When old, the outer layer of the cortex scales off, and the pycnidia may then be superficial, solitary or in small groups, on the inner tissues of the cortex. von Höhnel stated that the pycnidia were almost free, and placed *Zythiostroma* in his Stromaceae, but in my specimens the pycnidia appear to be quite superficial on the stroma, and in old specimens the stroma is lacking.

CYANOPHOMELLA von Höhn. F. No. 60 (1918)

Type species, *Cyanophomella acervalis* (Sacc.) v. Höhn. F. No. 60 (1918).

Pycnidia globose with a flat ostiolum, superficial, seated singly or caespitose on an erumpent, more or less evident stroma; wall fleshy to membranous, large-celled parenchymatous, more or less blue or violet; conidiophores simple; conidia small, hyaline, rod-shaped.

CYANOPHOMELLA ACERVALIS (Sacc.) v. Höhn. F. No. 60 (1918); *Phoma acervalis* Sacc. *Syll. Fung.* III, 97 (1884); Fuckel, *Symb. Myc.* p. 166 (1869).

Pycnidia caespitose, minute, fuscous; conidia very small, cylindrical, oscillating.

On dry branches of *Salix Caprea*, Rhenogovia.

This species was recorded by Fuckel as the spermogonium of *Gibberella acervalis*, and was subsequently named by Saccardo, the description cited being Fuckel's. It has not been recorded in this country, but *Gibberella acervalis* has.

PYCNIDIELLA von Höhn. C. No. 906 (1915)

Type species, *Pycnidiella resinae* (Ehrenb.) v. Höhn. C. No. 906 (1915).

Pycnidia superficial, fleshy, ostiolate; wall thick, soft, obscurely plectenchymatous-fibrous; internally lined everywhere with simple or fasciculately branched sporophores; sporidia hyaline, small, globose or ellipsoid, one-celled. Pycnidial stages of discomycetes.

PYCNIDIELLA RESINAE (Ehrenb.) v. Höhn. C. No. 906 (1915); *Cytospora resinae* Ehrenberg, *Silv. Ber.* p. 28 (1818); *Sphaeria resinae* Fr. *Syst. Myc.* II,

453 (1823); *Tubercularia resinae* Thuem. *F. Austr.* No. 79; *Zythia resinae* (Ehrenb.) Karst. *Symb. Myc. Fenn.* XXI, 104 (1888).

Pycnidia gregarious or scattered, 0·2–0·3 mm. diameter, superficial, ovoid or sphaeroid, smooth, sordid red or orange red, ostiolate; wall 30–40 μ thick, densely plectenchymatous-fibrous without evident cellular structure; sporidia globose, hyaline, 1·5–2 μ diameter.

On resin of *Pinus sylvestris* and *P. austriaca*. The pycnidial stage of *Biatorella resinae* Mudd. The pycnidial stage has not been recorded for this country, though the perfect stage was recorded by Mudd, A. L. Smith, and Massee.

STYLONECTRIA von Höhn. C. No. 878 (1915)

Type species, *Stylonectria applanata* v. Höhn. C. No. 878 (1915).

Pycnidia superficial, with or without a stroma, like *Nectria* perithecia, but containing one-septate sporidia borne singly on short simple sporophores.

STYLONECTRIA APPLANATA v. Höhn. C. No. 878 (1915). Pycnidia scattered or gregarious, globose or oval, about 0·1 mm. diameter, with a flat apical disc which projects slightly over the body of the pycnidium, bright red becoming blood red; sporidia oval or oblong-oval, smooth, hyaline, one-septate, 9–12 × 4–4·5 μ.

The pycnidial stage of *Dialonectria applanata* (Fuckel) Petch; with the perithecial stage or separately, on effete pyrenomycetes. Guiting Wood, May 1938, on *Diaporthe decedens* on hazel.

STAGONOSTROMA Diedicke and *FUSIDOMUS* Grove

Pycnidia superficial, scattered or clustered, with or without a stroma, appearing black, but the wall blue or violet by transmitted light; wall parenchymatous, soft, large-celled; sporidia hyaline, oblong or fusiform, curved or straight, multiseptate; sporophores branched in *Fusidomus*, unknown in *Stagonostroma*. Pycnidial stages of *Gibberella*.

In *Notices of British Fungi*, No. 413* (1850), Berkeley and Broome described *Hendersonia arcus*, said to resemble in form and colour *Gibberella pulicaris*, with which it often grew. Its sporophores were described as branched, and its sporidia as elongated, curved, three-septate, swollen in the centre, attenuated to either extremity, hyaline. The type specimen grew on box twigs. No spore measurements were given.

Fuckel, in *Symbolae Mycologicae* (1869), enumerated pycnidial stages for several species of *Gibberella*, among them being '? macrostylospores', 26 × 6 μ, for *G. pulicaris*, found in immature perithecia, oblongo-fusiform, curved, three-septate, constricted at the septa, generally germinating; 'stylospores' in astomate pycnidia, oblong, one- to four-septate, sometimes constricted, 20–24 × 6 μ, for *G. Evonymi*; and '? macrostylospores', oblongo-fusiform, curved, three-septate, constricted, 26 × 6 μ, sometimes germinating, for *G. Saubinetii*. The last record is correctly entered in *Rabh. Krypt. Flora* under *G. cyanogena*, where it is stated that these stylospores occur in the young perithecia, and are similar to the ascospores, but smaller, narrower and more pointed, facts not given by Fuckel and probably incorrect.

In 1914, Diedicke (*Krypt.-Fl. Mark Brandenburg*, IX, 561 (1914)) established a new genus, *Stagonostroma*, with the species, *S. Dulcamarae* (Pass.) Died., evidently a pycnidial stage of a *Gibberella*. Grove stated that Diedicke described the spores as 'on inconspicuous pedicels', but Diedicke's phrase is 'sporenträger undeutlich'.

In 1919, von Höhnel, after examining the type specimen of Sydow's new genus, *Botryogene*, declared that it was an immature *Gibberella*, and that *Botryogene* = *Stagonostroma*. Of interest in the present discussion is that *Botryogene* was said to have sporidia on cylindrical pedicels, 15–30 μ long, each bearing one to four spores at the apex. von Höhnel transferred to *Stagonostroma*, *Hendersonia arcus* B. & Br. and *Stagonospora Euonymi* Sacc., the latter being Fuckel's stylospores on *Euonymus*.

In 1929, Grove (*J. Bot.* LXVII, 201–3) instituted a new genus, *Fusidomus*. His type is apparently *Fusidomus arcus* Grove, the only species described, but although this was described as '*sp.nov.*', it is evident from his later writings that he regarded it as the same as *Hendersonia arcus* B. & Br. Subsequently, his attention was directed to the work of Diedicke and von Höhnel, and in another paper (*J. Bot.* LXXII, 269–71 (1934)), he stated 'it is clear that this fungus of Diedicke's cannot be quite the same as *Fusidomus*, since the latter has its spores on conspicuous and persistent pedicels of a special character'. But, just as von Höhnel had dumped all these forms in *Stagonostroma*, so Grove, in the second volume of his *Stem and Leaf Fungi* (1937), placed them all in *Fusidomus*, including *Stagonostroma Dulcamarae* (Pass.) Died., the type of Diedicke's genus, *Stagonostroma*. That is clearly inadmissible, and if Grove's view is correct the name *Fusidomus* must be discarded.

There appear to be three kinds of spore phenomena in *Gibberella* which require elucidation. Perhaps the commonest is the occurrence, free in a perithecium, of rather large spores with rounded ends, like ascospores, usually in a state of germination. Multiseptate spores may also occur on short pedicels in immature perithecia, arising from hyaline tissue at the base of the perithecium; I have seen that only once, in an immature specimen of *G. pulicaris*, the spores being fusoid, equilateral and straight. Finally, there are the *Fusarium* conidiophores and the *Fusarium* spores described by Berkeley and Broome for *Hendersonia arcus*, and the foundation of Grove's *Fusidomus*; I have never met with a pycnidium containing these.

Fusidomus might be retained for the last named, but is it really needed? Grove wrote 'The explanation of these occurrences seems to be that the mycelium which ordinarily produces the *Fusarium* spores is here growing and producing them within a peridium that under other circumstances would have borne only asci and ascospores'. That appears to mean that *Fusidomus* is more or less an accident, and as the *Fusarium* has a name, at least sometimes, another name seems superfluous.

It is tempting to assume that Diedicke's *Stagonostroma* is Fuckel's stylosporic pycnidium. But the evidence is quite insufficient to support that conclusion. Unless a re-examination of the type throws more light on the origin of the spores the problem appears to be insoluble.

It might be thought a simple matter to examine these forms by modern methods and determine the mode of origin of the spores. Actually that is not so. These so-called pycnidia apparently occur at random among the perithecia, and there does not appear to be any way of identifying them beforehand. Nor, in my experience, can a specimen be definitely labelled as pycnidial. I have examined specimens assigned to *Fusidomus* by Grove, without finding anything resembling it. That does not imply that the labelling was incorrect, but probably that the original examination removed the *Fusidomus* pycnidia.

In a specimen of *Gibberella cyanogena* on *Brassica* stalks, gathered on 7 October 1941, the first perithecium examined had disorganized contents containing loose spores. Some of the spores were greatly constricted at the septa, and others were breaking up into separate cells, while many of them were in an advanced stage of germination. Some were adherent in clusters of four. Five other perithecia contained normal asci and ascospores, while a sixth had normal asci, but a few spores swelling and breaking up in the ascus.

An examination was then made of the perithecia situated on one stroma. Seven of these had normal contents, except for an occasional ascus containing spores breaking up into parts. One contained germinating spores with no clear evidence of their origin. The ninth (it was actually the first to be examined) contained immature asci with granular contents and no indication of spores, normal asci and ascospores, and ascus masses, i.e. the contents of an ascus, with eight or four spores adherent in a group the shape of an ascus, but without an evident ascus wall. Many of the spores in a mass had broken up into separate segments, which were rounded off, oblong-oval, globose, or, if terminal, ovate. Many of the spores were germinating while still in the ascus mass, and those in an early stage of germination left no room for doubt that the hyphae were germ tubes, not conidiophores.

I have found loose germinating spores in perithecia of *Gibberella* on several occasions, but the above was the first time I had been able to trace their origin from the asci. It seems most probable that, in general, germinating 'stylospores' in *Gibberella* perithecia are ascospores. They differ in shape from the *Fusarium* spores.

Grove's species of *Fusidomus* cannot be reclassified on the existing information, but the following notes may be of service.

Fusidomus arcus (B. & Br.) Grove is probably a stage of *Gibberella pulicaris*. Grove's figure agrees with the conidiophore of *Fusarium sambucinum*. It is to be noted that the

figure of the mature spores in his book is not quite the same as that in the *Journal of Botany*.

Fusidomus pulicaris Grove refers to the macrostylospores, and is not *Fusidomus*.

Fusidomus Euonymi Grove. I was unable to find pycnidia or perithecia on the Norfolk specimen cited by Grove. His description was taken from Fuckel, and refers to stylospores.

MYCORHYNCHUS Sacc. *Syll. Fung.* XVIII, 418 (1906)

Type species, *Mycorhynchus Marchalii* (Sacc. & March.) Migula, W., *Krypt.-Fl. Deutschland, Deutsch-Oesterreich und der Schweiz* (1921), p. 477.

Pycnidia subglobose below, with a long subulate beak, membranous, light-coloured; wall of the venter of large parenchymatous cells, those of the beak elongated, more or less parallel; sporidia hyaline, fusoid, acute, one-septate, sometimes shortly pedicellate.

MYCORHYNCHUS MARCHALII (Sacc. ex March.), Migula, W., *Krypt.-Fl. Deutschland, Deutsch-Oesterreich und der Schweiz* (1921), p. 477; *Rhynchomyces Marchalii* Sacc. in March. *Champ. Copr.* VI, 28 (1891).

Pycnidia superficial, gregarious, or clustered in subglobose tufts up to 0·5 mm. diameter on a delicate plectenchymatous pale brown stroma; pycnidia usually hyaline, venter flask-shaped, about 66 μ high, 40 μ diameter, passing into a long beak, up to 300 μ high, 25 μ diameter below; sporidia fusoid, attenuated below, sometimes into a thin appendage (pedicel), centrally one-septate, slightly curved, 40–63 × 6–7 μ, with a mucous coat which swells up strongly in lactic acid. The sporidia are apparently attached by a short pedicel to the base of the pycnidium; on extrusion they frequently adhere in clusters of two or four.

On decaying stalks of *Brassica*, North Wootton, June 1935. On horsedung, Walton, Liverpool (Travis), *teste* Grove.

See Petch, *Ann. Myc.* XXXIV, 74, 75 (1936), for resemblance to *Treleasia Sacchari* Speg.; and *Trans. Brit. myc. Soc.* XXV, 173 (1941), for comparison with *Rhynchonectria longispora* (Phil. & Plowr.) v. Höhn.

Saccardo named Marchal's fungus *Rhynchomyces Marchalii*, and later, as that generic name was preoccupied, he substituted *Mycorhynchus*, but he omitted to 'make the combination', *Mycorhynchus Marchalii*.

In *Mitt. Tech. Hochs. Wien*, I, 60 (1924) Weese recorded that on the original specimen of *Nectria helminthicola* B. & Br., collected at Batheaston, January 1859, he found a pycnidial form with smooth, long-ellipsoid, thick-walled spores, 6–12 × 4–6 μ, hyaline becoming brown, still one-celled, with an oil drop in the middle dividing the plasma in two. He suggested that when better material made complete observation on the final form of the sporophore and sporidia possible a new genus, *Styloletendraea*, might be established.

NECTRIOIDEAE-ASTOMAE

Pycnidia without an ostiolum, finally splitting irregularly and usually opening widely.

I. Sporidia oval, hyaline, one-celled	
(*a*) Sporophores mostly branched	*Pseudopatellina* v. Höhn.
(*b*) Sporophores absent	*Sclerozythia* Petch
II. Sporidia hyaline, two-celled, not catenulate	*Cystotricha* B. & Br.
III. Sporidia olivaceous, two-celled, pycnidia erumpent	*Pseudodiplodia* Karst.
IV. Sporidia long-cylindrical, two-celled; pycnidia globose, parenchymatous	*Trichocrea* March.

PSEUDOPATELLINA von Höhn. C. No. 179 (1908)

Type species, *Pseudopatellina conigena* (Niessl) v. Höhn. C. No. 179 (1908).

Pycnidia immersed, erumpent, soft, light-coloured, fleshy membranous, finally splitting above and then patellate; sporophores filling the whole interior, long, linear, branching and anastomosing [but see below]: sporidia continuous, apical on the sporophore.

PSEUDOPATELLINA CONIGENA (Niessl) v. Höhn. C. No. 179 (1908); *Dacrymyces conigenus* Niessl in *Rabh. Fung. Europ.* No. 2628; *Dendrodochium album* Bayliss Elliott in *Trans. Brit. myc. Soc.* VI, 57, Pl. I, figs. 8–11 (1918).

Pycnidia various, circular, oval, or elongated, shallow, at first completely immersed, with a continuous, hyaline, small-celled plectenchymatous wall about 10μ thick, opening by the disintegration of upper wall and the overlying host-tissue, and becoming patellate, pale yellow, pallid when wet, surrounded by the upturned tissue of the host and pycnidial wall, base sometimes convoluted; conidiophores elongated conoid, about 12 × 1·5μ, completely lining the pycnidium, arising directly from the wall, or in small clusters at the apices of short hyphae, or laterally on long, flexuose, branching and anastomosing hyphae, about 1μ diameter, which run indefinitely through the pycnidium; sporidia apical on the sporophores, hyaline, continuous, oblong oval, 2 × 1μ, with a few globose, 1μ, persisting involved in mucus.

On fallen cones of *Pinus sylvestris*, Tanworth-in-Arden (Bayliss Elliott); North Wootton, Norfolk; Hubberholme, Yorks.

von Höhnel appears to have overlooked the stratum of sporophores on the pycnidial wall, while Mrs Bayliss Elliott did not record the long sporiferous hyphae described by von Höhnel; both may depend on the stage of development reached by the pycnidium, but they occurred together in my specimens. When the overlying tissue disintegrates, fragments consisting of single host cells, or small groups of host cells, with pieces of the pycnidial wall and sporophores attached, may remain in the mass of conidia; these recall the 'cells' described and figured by Corda as occurring in the spore masses of *Phymatostroma* and *Leucosporium*.

SCLEROZYTHIA Petch, in Grove, II, 363 (1937)

Type species, *Sclerozythia Brassicae* Petch, in Grove, II, 363 (1937).

Pycnidia superficial, bright coloured, astomate, solid, parenchymatous; sporidia hyaline, continuous, in parallel rows in the parenchyma; no conidiophores.

SCLEROZYTHIA BRASSICAE Petch, in Grove, II, 363 (1937).

Pycnidia scattered or gregarious, superficial, ovoid or subglobose, up to 250μ diameter, dark amber, then dull red, glabrous, with a thick parenchymatous wall of large cells, up to 27 × 22μ, pale yellow becoming red, internally hyaline, parenchymatous, at first closed, then opening by a pore; sporidia oblong-oval, continuous, smooth, hyaline, 15–30 × 7–11μ, formed in short parallel lines in the parenchyma, not persisting in chains.

On decaying stems of *Brassica*, North Wootton, Norfolk, June 1935.

Zythia Brassicae Sacc. & Roum. appears to be a similar species, but the sporidia are different, according to the description.

In the description in Grove, II, 118, 'dark amber' is printed 'dark umber', with a corresponding error in the Latin description, p. 363.

CYSTOTRICHA B. & Br. *Ann. Mag. Nat. Hist.* (2), v, 457 (1850)

Type species, *Cystotricha striola* B. & Br. *Ann. Mag. Nat. Hist.* (2), v, 457 (1850).

Pycnidia growing on wood, superficial or nearly so, horizontally elongated, opening by a longitudinal fissure. Sporophores branched, jointed, submoniliform, here and there beset laterally and terminally with oblong, hyaline, uniseptate sporidia.

CYSTOTRICHA STRIOLA B. & Br. *Ann. Mag. Nat. Hist.* (2), v, 457 (1850), Pl. 12, fig. 10; Grove, *British Stem and Leaf Fungi*, II, 145; *Pseudopatella Tulasnei* Sacc. *Syll. Fung.* III, 688 (1884); *Cystotricha compressa* (P.) v. Höhn. C. No. 538 (1910).

Pycnidia punctiform or linear, often arranged in short lines, appearing black with a reddish tinge, but the tissue brownish wine-red; disc reddish; soft-fleshy, the tissue small-celled plectenchymatous; spores oblong, acrogenous and pleurogenous, hyaline, continuous, then one-septate with the septum very delicate, 7–10 × 3 μ; sporophores long, cylindrical, once or twice branched above, septate from the base, submoniliform, the joints about as long as broad (Grove and von Höhnel).

On decorticated wood, Batheaston, Somerset; King's Cliffe, Elton, Northants; Wiltshire.

The pycnidial stage of *Durella compressa* Tul. (*Peziza compressa* Pers.), hence von Höhnel's name. Not recorded under *Durella compressa* by Phillips or Massee.

PSEUDODIPLODIA Karsten, *Symb. Myc. Fenn.* XV, 156 (as subgenus), Sacc. *Syll. Fung.* III, 621

Type species, *Pseudodiplodia ligniaria* Karst. *Symb. Myc. Fenn.* XV, 156 (1884).

Pycnidia more or less superficial, globose, waxy-fleshy, fuliginous when moist, soon opening with a wide mouth; sporidia ellipsoid, one-septate, pale olivaceous.

PSEUDODIPLODIA CORTICIS Grove, *J. Bot.* (1886), p. 197, Pl. 266, fig. 6.

Pycnidia gregarious, or collected in short lines or spots, globose or oblong, erumpent, then nearly superficial, when dry brownish-black, smooth, shining, 1–1·4 mm. diameter, pierced by a small pore which soon widens and exposes a disc; wall soft, waxy, olivaceous, subferruginous, minutely parenchymatous; sporophores somewhat branched, fasciculate, twice or thrice as long as the spore; sporidia oblong, subfusoid, obtuse at both ends, or pointed at one end, rarely somewhat curved, for a long time continuous, but finally delicately one-septate, hyaline singly, pale olive in mass, 10–14 × 3–4 μ (Grove).

On the inner side of bark of sycamore, Sutton Coldfield.

TRICHOCREA Marchal, *Champ. Copr.* VI, 14 (1891)

Type species, *Trichocrea stenospora* March. *Champ. Copr.* VI, 14, (1891).

Pycnidia superficial, ovoid, light-coloured, rather soft and waxy, at first closed, then widely open and almost discoid, texture parenchymatous;

sporidia very numerous, narrow cylindrical, one-septate, hyaline; sporophores elongated, filiform, densely fasciculate, branched above.

Trichocrea oödes Bayliss Elliott, *Trans. Brit. myc. Soc.* vi, 58 (1918), Pl. I, figs. 12–16.

Pycnidia gregarious, superficial, ovate, stalked, 130–190 × 180–200 μ, with a stalk, 50–100 μ long, shining, whitish; texture of very narrow, interwoven, septate hyphae; at first closed, then open, margin fringed with converging hairs; sporidia linear, straight, some slightly bent and thicker in the middle, hyaline, pluriguttulate, not septate, 30–60 × 0·5 μ; sporophores branched, arising in dense fascicles from the base of the pycnidium.

On a fallen cone of *Pinus sylvestris*, Tanworth-in-Arden, Warwickshire.

As pointed out by Mrs Bayliss Elliott, it seems doubtful whether this species is correctly placed in *Trichocrea*, as the pycnidium is not parenchymatous and the sporidia have not been observed to be septate.

PATELLOIDEAE

Pycnidia becoming widely concave, with sporophores more or less confined to the base, thus forming a discoid hymenium.

PATELLOIDEAE-PATELLATAE

Pycnidia white or light-coloured, membranous to fleshy, soft.

I. Sporidia hyaline, one-celled, not ciliate	
A. Sporidia fusoid, curved; sporophores short	*Hainesia* Ell. & Sacc.
B. Sporidia small, globose; sporophores long, branched	*Catinula* Lév.
II. Sporidia hyaline, one-celled, ciliate at both ends	
A. Sporidia ovoid	*Chaetospermum* Sacc.
B. Sporidia cylindrical	*Ciliospora* Zimm.
III. Sporidia hyaline, one-celled, catenulate	
A. Receptacle sessile	*Patellina* Grove *non* Speg.
B. Receptacle stalked	*Siroscyphella* v. Höhn.

HAINESIA Ellis & Sacc. *Syll. Fung.* iii, 698 (1884)

Char. emend. von Höhnel, F. No. 67 (1918).

Type species, *Hainesia rhoina* Ellis & Sacc. *Syll. Fung.* iii, 698 (1884).

Pycnidia immersed, then erumpent, patellate, widely and circularly open above, base small-celled parenchymatous; excipulum almost smooth externally, light-coloured, fleshy, composed of parallel hyphae; sporophores simple, or long fasciculately branched (as in *Tubercularia*); sporidia terminal, and lateral on very short branches, hyaline, continuous, fusoid, curved.

Grove included this genus, with the species, *Hainesia Rubi* (Westend.) Sacc., which he suggested should be taken as the type. The type, however, is *Hainesia rhoina*, and *Hainesia Rubi* is not a *Hainesia*, but a member of the Tuberculariae, *Leptosporium Rubi* (Westend.) v. Höhn., *Leptosporium* Sacc. non Bonorden, *teste* von Höhnel, F. No. 67 (1918). There are no known British species of *Hainesia*.

CATINULA Lév. *Ann. Sci. nat.* IX, 247 (1848)

Type species, *Catinula aurea* Lév. *Ann. Sci. nat.* IX, 247 (1848).

Pycnidia superficial, at first closed, flat-discoid or pulvinate, then open and cup-shaped; sporophores long, branched; sporidia apical, globose.

CATINULA AUREA Lév. *Ann. Sci. nat.* IX, 247 (1848); *Lemalis aurea* (Lév.) Sacc. *Syll. Fung.* III, 672 (1884); Elliott and Stansfield, *Trans. Brit. myc. Soc.* VIII, 252, fig. 4 (1923); Grove, II, 131, fig. 61; *Dendrodochium citrinum* Grove, *J. Bot.* 1886, p. 18, Pl. 267, fig. 8.

Pycnidia superficial, at first closed, pulvinate, flattened, or globose, then cup-shaped or urceolate, sheathed below, often with a spreading rim, lemon yellow; receptacle parenchymatous below, composed towards the margin of parallel, thick-walled hyphae, 1·5–2 μ broad; sporophores parallel, long, fasciculately branched; sporidia apical, globose, hyaline or yellowish, 1·5–2 μ diameter, very numerous, united by mucus.

On cones and wood of *Pinus sylvestris*, Barnt Green, Warwickshire (Grove); Tanworth-in-Arden (Bayliss Elliott); North Wootton (Petch).

Saccardo, in *Syll. Fung.* III, 672, placed *Catinula aurea* in *Lemalis* Fr., but that is inadmissible as it is the type species of the genus *Catinula*, and, moreover, the type of *Lemalis* Fr. is a discomycete, *teste* von Höhn. C. No. 551 (1910).

Catinula turgida Desm., recorded in *Trans. Brit. myc. Soc.* XV, 3, is *Psilospora turgida* (Desm.) v. Höhn. C. No. 913 (1915), and belongs to von Höhnel's section Stromaceae.

CHAETOSPERMUM Sacc. *Syll. Fung.* X, 706 (1892)

Type species, *Chaetospermum chaetosporum* (Pat.) A. L. Smith & Ramsbottom, *Trans. Brit. myc. Soc.* IV, 328 (1914).

Pycnidia gelatinous; sporophore branched; sporidia ovoid, hyaline, with setae at each end.

CHAETOSPERMUM CHAETOSPORUM (Pat.) A. L. Smith & Ramsbottom, *Trans. Brit. myc. Soc.* IV, 328 (1914); von Höhn. H. I, 86 (1924); *Tubercularia chaetospora* Pat. *Bull. Soc. Myc. France*, IV, p. xl with fig. (1888); *Chaetospermum tubercularioides* Sacc. *Syll. Fung.* X, 706 (1892).

Pycnidia sessile, scattered or gregarious, 0·5–2 mm. broad, white, gelatinous, orbicular; sporophores hyaline, branched; sporidia ovoid, 38–43 × 8–10 μ, hyaline, copiously guttulate, furnished with seven to eight setae, equal in length to the sporidium.

On decaying leaves, in a wood near Rodborough Common, September 1913.

CILIOSPORA Zimm. *Zentr. f. Bakt.* Abt. 2, VIII, 217 (1902)

Type species, *Ciliospora gelatinosa* Zimm. *Zent. f. Bakt.* Abt. 2, VIII, 217 (1902).

Pycnidia superficial, gelatinous; sporidia continuous, hyaline, furnished with cilia at or near the ends.

CILIOSPORA ALBIDA (Massee & Crossl.) Grove, *British Stem and Leaf Fungi*, II, 117 (1937); *Dilophospora albida* Massee & Crossl. *Naturalist*, 1904, p. 3.

Pycnidia gregarious, rounded or elongated, up to 1 mm. long, whitish, gelatinous; sporophores short, erect, crowded, filiform; sporidia oblong-fusoid, obtusely rounded at the ends, hyaline, 28–40 × 6–8 μ, furnished at or near each end with up to five hyaline cilia.

On dead stems of *Epilobium hirsutum*, Hebden Bridge, Yorks.

It seems doubtful whether *Ciliospora* is distinct from *Chaetospermum*. The type of the former has long cylindrical spores.

PATELLINA Grove *non* Speg. *Brit. Stem and Leaf Fungi*, II, 131 (1937)

Type species, *Patellina caesia* Elliott & Stansf. *Trans. Brit. myc. Soc.* VIII, 250 (1923).

Excipula between cup-shaped and saucer-shaped, fleshy, glabrous (? always), sessile, bright coloured. Spores globose, ellipsoid, or cylindrical, unicellular, hyaline, growing in chains at the apex of long cylindrical hyphae (Grove).

PATELLINA CAESIA Elliott & Stansfield, *Trans. Brit. myc. Soc.* VIII, 250, Fig. 2 (1923); Grove, II, 132.

Receptacle patelliform, like the apothecium of a discomycete, grey, pubescent, about 1 mm. broad; sporidia cylindrical, hyaline, more or less obliquely truncate at both ends, about $10 \times 1{\cdot}5\mu$; sporophores fasciculate, branched, cylindrical, producing long chains of sporidia (Grove).

On cones of *Pinus sylvestris*, Tanworth-in-Arden.

PATELLINA DIAPHANA Elliott & Stansfield, *Trans. Brit. myc. Soc.* VIII, 251, Fig. 3 (1923).

Receptacle like that of *P. caesia*, but glabrous and entirely white; sporidia similar, but not in such long chains, $5–6{\cdot}5 \times 1–1{\cdot}5\mu$; sporophores long (Grove).

On dead roots of *Populus*, Tanworth-in-Arden.

Neither of these species agrees with the description of *Patellina* Speg., which was not described as having branched sporophores, or cylindrical sporidia, or sporidia in chains. Grove modified the generic description to fit them. But, *teste* von Höhn. in C. No. 908 (1915), *Patellina* Speg. is *Catinula* Lév. It is difficult to decide where these two fungi should be placed, as the details given are scarcely sufficient. Elliott and Stansfield described the receptacle of *P. caesia* as 'composed of pure white hairs arranged parallel to one another', and that of *P. diaphana* as 'composed of very narrow parallel hyphae'. The sporophores of *Sirocyphis* Clements were said to be simple, while *Siroscyphella* von Höhn. C. No. 549 (1910), which has branched sporophores and chains of cylindrical sporidia, was described as having a short, thick stalk. The type of the latter, *Siroscyphella succinea* (Fr.) v. Höhn. C. No. 1077 (1920), grew on needles of *Pinus*, and it was recorded under the name *Dacrymyces succineus* Fr. by Phillips and Plowright, who regarded it as a stage of their *Peziza electrina*, *Grev.* VIII, 155. Massee included it under Fries's name in *British Fung. Fl.* I, 67, and as a stage of *Orbilia succinea* Quél. in *British Fung. Fl.* IV, 495. *Patellina caesia* is probably *Siroscyphella succinea*.

As regards *P. diaphana*, the details given are somewhat contradictory, probably because its description is not independent, but partly a comparison with *P. caesia*. Elliott and Stansfield's Latin description says 'Conidiis similibus, non longe catenatis,...hyphis longioribus suffultis', and in their general account they state that the sporophores are branched, much longer than in *P. caesia*, and that the sporidia are lateral and do not cling together in chains. But Grove, probably translating the Latin description, gave 'spores similar, but not in such long chains'. If the sporidia are not catenulate, it is probably *Pseudozythia* v. Höhn.

There do not appear to be any type or authentic specimens of either of these species.

SIROSCYPHELLA von Höhn. C. No. 549 (1910)

Type species, *Siroscyphella succinea* (Fr.) v. Höhn. C. No. 1077 (1918).

Pycnidia superficial, glabrous, pezizoid, with a short, thick stalk, parenchymatous below; excipulum of parallel fibres, fleshy, light-coloured; sporophores crowded, fasciculately branched, with hyaline, cylindrical, continuous sporidia in chains.

Siroscyphella succinea (Fr.) v. Höhn. C. No..1077 (1918); *Dacrymyces succineus* Fr. *Hymen. Europ.* p. 699 (1874); Phil. & Plowr. *Grevillea*, VIII, 155 (1880); *Dacryomyces succineus* Fr. in Massee, *Brit. Fung. Fl.* I, 67 (1892); *Siroscyphella fumosellina* (Stärb.) v. Höhn. C. No. 549 (1910).

Pezizoid; disc 200–300μ broad, with a short, thick stalk, 120 × 120μ; excipulum 20μ thick, composed of parallel, brownish hyphae, thick-walled, about 5μ broad, truncate at the obtuse margin; stalk and hypothecial tissue of thick-walled parenchyma cells, 4–5μ broad; hymenium of crowded, very thin, fasciculately branched sporophores, 40–50μ long; sporidia cylindrical, straight, truncate, hyaline, continuous, 12–14 × 1·5μ, in long apical chains. The fungus is seated on a thin basal layer which consists of brown, thin-walled, interwoven hyphae, resting on the epidermis of the host (von Höhnel).

On pine needles, Forres; recorded by Phillips and Plowright as a stage of *Peziza electrina* Phil. & Plowr. According to von Höhnel, it is the pycnidial stage of *Pocillum fumosellum* (C. & E.) v. Höhn.

STROMACEAE

No true pycnidia; sporidia contained in loculi in or on a stroma.

(As there are few recorded British hypocreaceous genera in this group, von Höhnel's key has been discarded.)

A. Stroma fleshy, light-coloured, immersed; loculi immersed in the stroma — *Polystigmina* Sacc.

B. Stroma immersed, light- or dark-coloured; loculi in erumpent processes, usually cartilaginous or coriaceous — *Micropera* Lév.

C. Stroma superficial, fleshy; loculi immersed; sporidia rod-shaped — *Dothiorina* v. Höhn.

POLYSTIGMINA Sacc. *Syll. Fung.* III, 622 (1884)

Type species, *Polystigmina rubra* (Desm.) Sacc. *Syll. Fung.* III, 622 (1884).

Stroma foliicolous, immersed, discoid, flattened-convex, somewhat fleshy, reddish, internally plurilocular; sporidia filiform, curved or hooked, continuous, hyaline.

Polystigmina rubra (Desm.) Sacc. *Syll. Fung.* III, 622 (1884); *Septoria rubra* Desm. *Ann. Sci. Nat.* XIX, 342 (1843).

Stromata hypophyllous, roundish, rather flat or convex, fleshy, reddish yellow; loculi small, numerous, immersed, ostiola punctiform, opening on the under side of the leaf; sporidia linear, at first straight, becoming curved or hooked and thicker below, 25–30 × 1–1·5μ.

On leaves of *Prunus spinosa*, *P. insititia*, and *P. domestica*.

The pycnidial stage of *Polystigma rubrum* DC. The ascigerous stage of the latter develops after the leaves have fallen; consequently, records of *Polystigma rubrum* usually refer to *Polystigmina rubra*. There should be a corresponding name for the pycnidial stage of *Polystigma fulvum* DC., but it does not appear to have been invented.

MICROPERA Lév. in *Ann. Sci. nat.* (3), V, 283 (1846)

Type species, *Micropera drupacearum* Lév. *Ann. Sci. nat.* (3), V, 283 (1846).

Stroma immersed; pycnidial processes erumpent, becoming almost super-

ficial, generally densely caespitose, globoso-conoid or columnar; wall leathery, or corky, or cartilaginous, light- or dark-coloured, but not really black, composed of thick-walled cells; ostiola spurious; sporophores short, lining the wall; sporidia filiform-fusoid, straight or curved, hyaline, multiguttulate. Pycnidial stages of discomycetes.

Micropera drupaceárum Lév. *Ann. Sci. nat.* (3), v, 283 (1846).

Pycnidial processes leathery, immersed in the cortex, then erumpent, obovoid or subcylindrical, distorted by mutual pressure, red brown, appearing black, externally scurfy, orifice whitish; sporophores branched or fasciculate, subulate, up to 20μ long; sporidia narrowly cylindraceo-fusoid, curved or flexuose, hyaline, multiguttulate, 'at length one-septate' (Grove), 40–50 × 2–3μ.

On *Prunus avium* (Massee); wild cherry (Phillips).

The pycnidial stage of *Dermatea Cerasi* (Pers.) de Not., syn. *Cenangium Cerasi* (Pers.) Massee. Recorded for Britain by Phillips in *British Discomycetes*, p. 341, without name, and by Massee in *British Fungus Flora*, IV, 117, as *Micropera drupacearum*.

Micropera spúria (Fr.) v. Höhn. C. No. 950 (1916); *Sphaeronaema spurium* (Fr.) Sacc. *Syll. Fung.* III, 186 (1884); *Ceratostoma spurium* Fr. *Obs.* II, 338 (1818).

Pycnidial processes erumpent from an immersed white stroma, solitary or caespitose, conico-cylindrical, up to 3 mm. high, fragile, pulverulent, blackish brown; wall hyaline internally, brown externally; sporidia fusoid, curved, continuous, 18–24 × 3–4μ.

On *Prunus spinosa* (Phillips, Massee); *P. domestica* (Grove).

The pycnidial stage of *Dermatea prunastri* (Pers.) Fr., syn. *Phaeangella prunastri* (Pers.) Massee. Recorded for Britain by Phillips, p. 345, without name (sporidia 15 × 2μ, one-septate), and by Massee, p. 138, as *Sphaeronaema spurium* (sporidia 15 × 1·5–2μ, one-septate).

Micropera pádina (Pers.-Mougeot) Sacc., *Michelia*, II, 104; *Sphaeronaema brunneoviride* Auers. in herb.

Pycnidial processes subsolitary, ferruginous, apex blackening, conical, umbilicate above, then subpezizoid; sporophores short, filiform; sporidia cylindrico-fusoid, hyaline, 25–30 × 3·5–4μ.

On *Prunus Padus*. Cwm Llwch and Cerrig Gleisau (Grove). Grove's record on plum is withdrawn in II, 361.

The pycnidial stage of *Dermatea Padi* (A. & S.) Fr., which is not recorded for Britain by Phillips or Massee.

Micropera Cotoneástri (Fr.) Sacc. *Syll. Fung.* III, 605 (1884); *Sphaeria Cotoneastri* Fr. in Kunze, *Myk. Heft*, II, 46; *Sphaeronaema pallidum* Peck, *25th Report*, p. 85; *Micropera Sorbi* (Fr.) Sacc. *Syll. Fung.* III, 605 (1884), *teste* von Höhn. in C. No. 955 (1916); Grove, I, 448.

Pycnidial processes imperfect, loosely gregarious, up to 400μ diameter, 350μ high, erumpent but not prominent, conical, truncate, dark red-brown; texture of very small cells; sporophores verticillately branched (simple, v. Höhn.), 20–25 × 2·5μ (15–20 × 2–3μ, v. Höhn.), arising from a fuscous violet (Grove) (pale reddish, v. Höhn.) basal stratum; sporidia fusoid, acute, curved, continuous, 15–16 × 0·75–2μ.

On *Sorbus Aucuparia*, Bidston Hill, Cheshire (Grove).

According to Fuckel, the pycnidial stage of *Cenangium inconstans* (Fr.), which is not recorded for Britain by Phillips or Massee.

Micropera versiformis (A. & S.) Grove, II, 361; *Sphaeronaema versiforme* (A. & S.) Fr. *Scler. Suec.* III, No. 102; *Sphaeria versiformis* A. & S. *Consp. Fung.* p. 52 (1805).

Pycnidial processes conico-globose, with a minute pore at the apex; sporidia elongated ovoid, straight or slightly curved, hyaline, continuous, about $25 \times 6{\cdot}5\mu$.

On *Rhamnus frangula*, Shere; Highgate.

The pycnidial stage of *Dermatea Frangulae* Tul., syn. *Scleroderris Frangulae* Massee. Recorded for Britain by Phillips, p. 351, without name, and by Massee, p. 123, as *Sphaeronaema versiforme*.

Nannfeldt (1932) remarked that it was very doubtful whether *Dermatea Morthieri* (*Cenangium Morthieri* Fuckel) and its pycnidial stage, *Micula Mougeotii* Duby, were distinct from *Dermatea Frangulae* and *Sphaeronaema versiforme* respectively. The sporidia of *Micula Mougeotii*, syn. *Atractium Therryanum* Sacc., are said to be $46–50 \times 2–3\mu$.

Micropera turgida (B. & Br.) v. Höhn. F. No. 34 (1917); *Cryptosporium turgidum* B. & Br. *Ann. Mag. Nat. Hist.* (5), VII, 129 (1881).

Pycnidial processes scattered or fasciculate, dark-coloured, leathery, globose, ovate or shortly clavate, finally becoming patellate; sporophores simple, moderately long, about $30 \times 3\mu$; sporidia hyaline, continuous, fusoid, ends acute, straight or generally curved, $20–30 \times 4–5\mu$.

On *Fraxinus excelsior*, Twycross (Bloxam).

The pycnidial stage of *Dermatea Fraxini* (Tul.) v. Höhn. Not recorded by Phillips or Massee for Britain, but Massee's description of *Tympanis Fraxini* relates to an American species, *Godronia Fraxini* (Schw.) v. Höhn., *teste* von Höhn. F. No. 34 (1917).

DOTHIORINA von Höhn. C. No. 714 (1911)

Type species, *Dothiorina Tulasnei* (Sacc.) v. Höhn. C. No. 714 (1911).

Stromata pulvinate to globose, often confluent, superficial, fleshy, composed of almost parallel, vertical, very slender hyphae. Pycnidial loculi immersed, crowded, radially elongated, ostiolate, densely lined with linear, simple or fasciculately branched sporophores. Sporidia hyaline, small, rod-shaped.

Dothiorina Tulasnei (Sacc.) v. Höhn. C. No. 714 (1911); *Dothiorella Tulasnei* Sacc. *Syll. Fung.* III, 239 (1884); *sine nomine*, Tulasne, *Sel. Fung. Carp.* III, 188, Pl. XX, figs. 15–18.

Stroma even or tuberculate, dark green, paler internally, the exterior becoming black and somewhat carbonaceous when old; sporidia rod-shaped, continuous, straight, $3–5 \times 1\mu$.

On wood coloured by *Chlorosplenium*. North Wootton, March 1942.

The pycnidial stage of *Chlorosplenium aeruginosum* (Oed.) de Not., with the ascigerous stage, or independently on wood coloured green by the latter.

von Höhn. C. No. 714 (1911) placed this genus in the Nectrioideae, but in F. No. 74 (1918) he stated that it belonged to the Stromaceae (Pachystromaceae-carnosae).

ADDENDA

In C. No. 548 (1910) von Höhnel placed the following genus in the Nectrioideae, but in his key in his *System der Fungi Imperfecti* it is placed in the Sphaerioideae. Grove has it in Nectrioideae.

ERIOSPORA B. & Br. *Ann. Mag. Nat. Hist.* (2), v, 455 (1850)

Type species, *Eriospora leucostoma* B. & Br. *Ann. Mag. Nat. Hist.* (2), v, 455 (1850).

Stroma multilocular; loculi flattened globose, with a common orifice; wall thick, with a dark outer layer and a more or less gelatinous, hyaline, inner layer; sporidia filiform, several at the apex of a rod-like sporophore.

ERIOSPORA LEUCOSTOMA B. & Br. Spots pitchy black. Stromata depressed, effused, thin, margined, scarcely 2 mm. broad, multilocular, dehiscing in the centre by a papillate white-bordered, pulverulent opening; loculi varying in number, subglobose or confluent and flattened; sporidia (or spore appendages) filiform, often curved or hooked at the upper end, 50–70 × 0·75–1 μ, seated in bundles of three to six on a short cylindrical or oblong base or pedicel (Grove, II, 120).

On dead leaves of *Typha*, Spye Park, Wilts, February 1850; apparently not found again in this country.

This species was reported from Germany, on *Carex sylvatica* and *C. stricta*, by Fuckel, who issued specimens in *Fungi Rhenani*, No. 1726. These were examined by von Höhnel, who described them in C. No. 548 (1910). His description differs in several respects from those of Berkeley and Broome, and Grove, and is quoted below in some detail.

According to von Höhnel, the fungus is not multilocular. It has simple, gelatinous-fleshy pycnidia, 300-400 μ broad, circular, often somewhat elongated, slightly depressed, immersed beneath the epidermis. The wall consists of two layers. The outer layer is 6–7 μ thick, yellow-brownish, soft and of indeterminate structure, containing concretions (? of calcium oxalate), and not sharply limited from the surrounding tissue. The inner layer is hyaline, soft, gelatinous, 25–35 μ thick, and contains a network of hyaline hyphae, 1 μ broad, with meshes, 5–7 μ broad. From this network arise distant, hyaline, simple, inwardly directed rods, about 6–8 × 1 μ, which bear at the apex 2–6 linear, one-celled, straight or slightly curved, hyaline spores, up to 100 × 0·7 μ. The spores may be extruded singly, but often attached to the basal rod. The fungus breaks through the epidermis with a cylindrical, flattened, not projecting, white ostiolar papilla, 60–70 μ broad and about 80 μ high. The tissue of the papilla consists of hyaline, thick-walled, soft cells, 2–3 μ diameter which merge gradually into the gelatinous inner layer of the pycnidium. The ostiolum is inconspicuous, and the host tissue is browned round the small flat ostiolar disc.

Zythia Fragariae Laibach, *Arb. biol. Anst. Berl.* VI, 79 (1908); *Phyllosticta grandimaculans* Bubák & Krieger, *Ann. Mycol.* X, 46 (1912).

Pycnidia amphigenous, immersed, appearing as dark, but not black, dots, then erumpent, whitish, wall pale brown when old, globoso-conoid, up to 0·3 mm. diameter; sporophores simple or branched near the base, conoid or flask-shaped, 12–18 × 2 μ, sometimes bulbous and 3 μ diameter at the base, apex acute; sporidia cylindrical, ends rounded and guttulate, 5–7 × 2 μ.

On pale yellowish brown blotches with a narrow dark purple border on leaves of strawberry. Kent and Gloucestershire (Dr H. Wormald).

(*Accepted for publication* 25 *July* 1942)

THE LIFE HISTORY OF *PHYTOPHTHORA CACTORUM* (LEB. & COHN) SCHROET.

By ELIZABETH BLACKWELL, *Royal Holloway College*

(With 7 Text-figures)

The strain

Twenty years ago, at the Imperial College of Science, London, Mr R. J. Tabor gave me a tube culture of *Phytophthora Cactorum* (Leb. & Cohn) Schroet., a strain which he had obtained from the Centraalbureau voor Schimmelcultures, Baarn, Holland, and he suggested that I should report on it. He informed me that although the structure and development of a *Phytophthora* with amphigynous antheridia had recently been described (Pethybridge, 1913, 1914; Murphy, 1918), the life history of a species with paragynous antheridia had not been told, and as far as I know this is still true to-day. My report was read at a meeting of the British Mycological Society in 1925 but was not published because, at that time, oospores had not been germinated in sufficient quantity to give all the stages of germination. Since then, however, oospores have been obtained in great numbers by a method of refrigeration (Blackwell, 1935).

The history of the species

The species was erected by Lebert and Cohn (1871) for an oomycete they found causing a rot of cacti. They called it *Peronospora Cactorum*. The Latin diagnosis sufficiently applies to the fungus here described, and the two text-figures satisfactorily illustrate it.

De Bary (1876) proposed a new genus *Phytophthora* based on *Peronospora infestans*.

Further species of *Phytophthora* were then recognized, and these de Bary (1881) collected, together with *P. Cactorum*, into an omnibus species *P. omnivora*. He recognized the validity of the name *P. Cactorum* but considered *P. omnivora* more suitable.

Schroeter, however (1886), recognized the original specific epithet *Cactorum*, and *Phytophthora Cactorum* it remains to this day.

Parasitism

Diseases of a number of plants and parts of plants, e.g. crown rot, foot rot, root rot, die back, damping off, have been attributed to *Phytophthora Cactorum* among such widely different genera as *Cereus*, *Acer*, *Pyrus*, *Paeonia*, *Rheum*, *Fagus*, *Pinus* and others. The species comprises a number of distinct strains (Tucker, 1931, 1933).

Cultivation

In the early days of the investigation the fungus was grown on potato mush agar at a temperature of 22° C. Trials on prune agar and malt agar gave a much thinner growth; prune agar proved useful in encouraging sporangial

production. On malt agar the growth was stunted, the mycelium being not only sparse but nodular. Latterly it has been conveniently grown at laboratory temperature (15–20° C.) on ground Quaker-oat agar, oatmeal agar or bean agar for production of oospores, and on Difco corn-meal agar for production of sporangia. It is, however, easily enough cultivated on a variety of media, and it can endure a wide range of temperature. It has been subcultured continuously in the laboratory these twenty years, and during this prolonged saprophytic existence no change has been observed in its vigour, or in size and abundance of reproductive organs. A subculture was sent to Professor Leonian in 1940 who wrote: 'I have examined the culture and find it to be a typical one.'

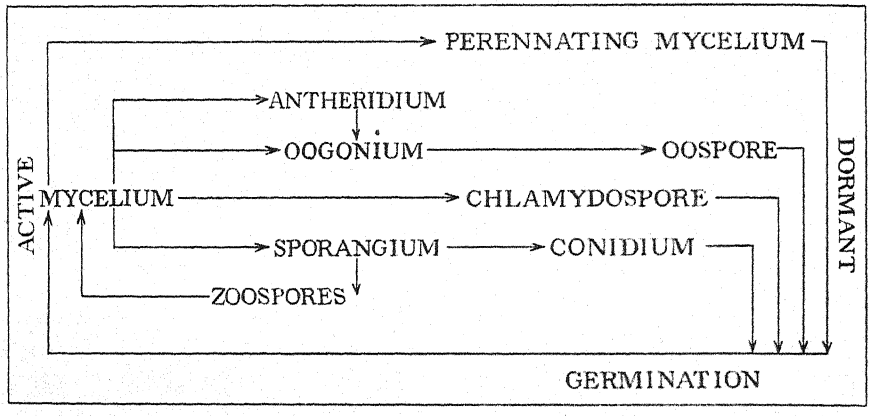


Fig. 1. A diagrammatic representation of the life cycle of *Phytophthora Cactorum*.

Vegetative growth and form of the mycelium

The macroscopic appearance of the mycelium varies with the medium in which it is growing. It is sometimes abundant and fluffy and sometimes sparse and close, and in slightly acid water it is fine and free with abundant sporangia on long thin hyphae reaching up to the surface of the water.

Microscopically it shows the right-angled branching characteristic of the genus, with a slight constriction at the base of each branch (Fig. 4). The hyphae are variable in diameter (2–14μ); they are slender and slightly branched in a watery medium; but short, thick and much branched, even swollen and nodular, in a medium that is highly concentrated and relatively dry. For the most part when not under extreme conditions hyphae measure 4–5μ across and branch frequently, rather more vigorously on one side than the other; but vegetative branching is always monopodial, in contrast to the unichasial sympodium of the sporangiophore. As the culture develops the main straight hyphae grow along the surface of the agar, giving off lateral branches both immersed and emergent. Growth is at the tip of each branch and here the nuclei divide. There is often a nucleus at the base of a newly formed branch: presumably the sister nucleus of that which passed into the young branch. Nuclei are distributed singly

and evenly throughout young hyphae at intervals of 10–20μ apart, with sap vacuoles between them. There is constant movement of the protoplasm, and vacuoles can be watched forming and changing shape and running together. The wall at the tip of each young growing hypha is thin and extensible and permeable and it gives a slight reaction for cellulose but none for pectic substances and none for chitin. It is here that absorption of nutrients takes place as well as growth in length. Older hyphae have a film of protoplasm lining the wall, in which the nuclei are not readily discernible; while the central, almost continuous vacuole is packed with highly refringent oil reserves. Cross-walls are formed in young hyphae only at the base of the reproductive organs: in older hyphae they may be anywhere and may be frequent. They are often accompanied by an extra plug of cellulose. The old hyphal walls are very resistant but these, too, give no reaction for pectic substances or chitin.

Mode of origin of the mycelium

Provided that oxygen, water and food are available, and staling substances are removed, the mycelium appears to have almost unlimited growth; and has extraordinary powers of resistance and recuperation. If it is not completely desiccated, it can lie dormant for months at just above freezing point and then revive in water. Indeed, the usual laboratory method of propagation has been by inoculation of a fresh nutrient medium with a piece of vegetative mycelium. In old, dormant mycelia portions of hyphae are plugged off from the rest. These include protoplasm packed with oil reserves, and have a 'glassy' look. It is this dormant protoplasm (Fig. 2 *f*) that renews the growth of the mycelium.

In addition to these irregular pieces of dormant hyphae, there are rarely developed, and as a rule only in water, spherical portions that can renew the growth by putting out fresh hyphae (Fig. 2 *g*). They are comparable with the sphaero-conidia described by Lafferty and Pethybridge (1922).

There are four kinds of resting spore that give germ tubes through a pore in the resistant wall: conidium (Fig. 2 *b*), resting conidium (Fig. 2 *c*), chlamydospore (Fig. 2 *d*) and oospore (Fig. 2 *e*). No hard and fast line can be drawn between the first three of these (Blackwell & Waterhouse, 1931).

In young fresh cultures in a saturated atmosphere, the mycelium is constantly originated by the germination of zoospores liberated from sporangia (Fig. 2 *a*, *s*).

Comparative review of the spores which originate new mycelium

The oospore, retained within its oogonium wall, is formed from the oosphere on fertilization by a nucleus from an antheridium. It has a most resistant double envelope: (1) the oogonium wall, and (2) the oospore wall which is thickly lined with a layer of reserves. In the dormant state it is uninucleate, becoming multinucleate on preparation for germination.

The chlamydospore has a single envelope which is sooner or later lined with a layer of reserves and it is superficially like the oospore but the absence of the oogonium wall and applied antheridium serves to distinguish it.

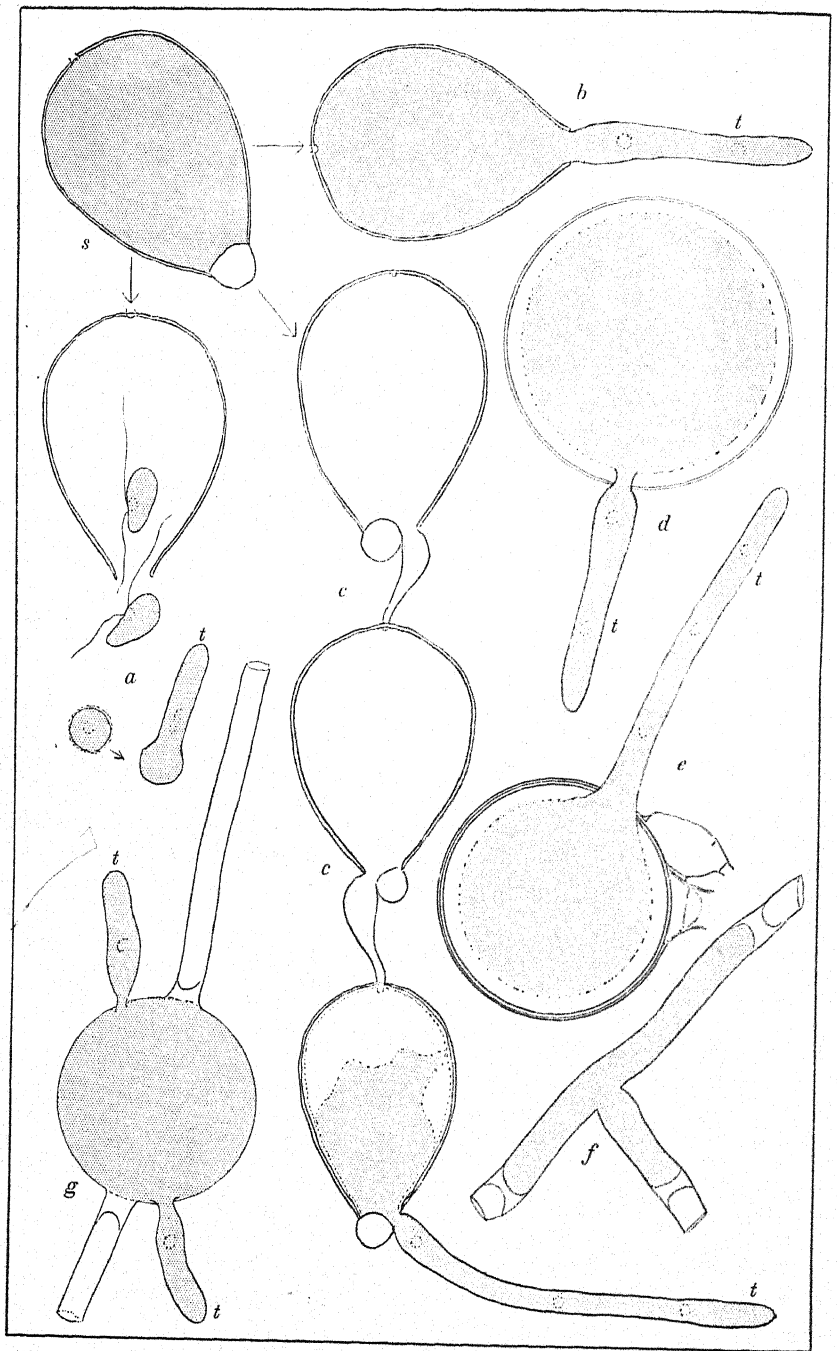


Fig. 2. The different initials from which the mycelium may be originated. (*a*) germinating zoospore, (*b*) conidium, (*c*) resting conidium, (*d*) chlamydospore, (*e*) oospore, (*f*) perennating mycelium, (*g*) 'sphaero-conidium', (*s*) the sporangium which by indirect germination may give zoospores or may develop into a conidium, (*t*) germ tube. (As seen in optical section × 1000; semi-diagrammatic.)

It is, as a rule, larger than the oospore and is formed under uneven conditions of alternating heat and cold, damp and drought. It is multinucleate from the first.

The conidium although arising like a thin-walled chlamydospore differs typically in the thinner lining of reserves and the presence of a papilla. It is ovoid and multinucleate and was initiated as a sporangium but failed to come into contact with fresh water until too late for the protoplasm to break up into zoospores.

The zoospore is liberated as a small, pear-shaped, uninucleate, biflagellate motile spore from the ovoid papillate sporangium.

All these spores germinate by giving germ tubes.

The germ tube of the zoospore is at first uninucleate but that of the oospore, the conidium and the chlamydospore is multinucleate and, as it grows, more nuclei pass out from the spore into the young hypha.

The germ tube of the zoospore, conidium and chlamydospore grows from an asexual spore and takes up again the interrupted growth of the parent mycelium; whereas that of the oospore starts a new individual: the result of a fusion of two nuclei.

The zoospore germinates at once or dies, as it cannot withstand drought. Conidia and chlamydospores can withstand drought, but on addition of water they germinate more or less readily. The oospore germinates only after a period of rest and under very narrowly limited conditions which are not easily determined.

Conidia, chlamydospores and oospores are *perennating* spores and of these the oospore is highly resistant. All three seem to be quite immune to the action of bacteria as long as they remain dormant.

The oospore is unique among the resting spores in that it comes in the natural sequence of growth in the life cycle of the fungus. Once the mycelium is established the production of sporangia and oogonia, with antheridia, follows, and under conditions of accumulation of staling substances, drought, inconstant temperature and such like are the other resting spores formed. It is unique too in that it forms a highly resistant wall *within* the parent hyphal wall (which is the oogonium wall), the other spores using the parent hyphal wall as their resistant wall. Thirdly it is unique in its need of a period of rest. During a period after maturation it is extremely difficult, if not impossible, to induce germination by any artificial means. Apart from this, all the other characteristics of dormancy are shared in common with the other perennating organs: viz. protoplasm with a minimum of imbibed water, reserves of food material, and an impermeable wall.

Production of spores

Reproductive organs are readily and abundantly produced in culture and may appear at once. A good supply of oxygen, water and nutrients encourages vegetative growth at first, but within two or three days both sporangia and oogonia, with antheridia, may be formed. In a fresh culture on ground Quaker-oat agar grown on the laboratory bench (usually about 14° C., but varying between 7 and 24° C.) oogonia can be found on the second day after inoculation, and later in abundance with an occasional

sporangium. On the other hand, in a fresh culture on Difco corn-meal agar, or in water only, sporangia appear on the second day, and later in abundance, with a few oogonia. Sporangia that will give zoospores are most readily obtained in fresh cultures growing in fresh media. If, however, these sporangia, while freshly ripe, do not originate zoospores they mature into conidia which germinate directly by germ tube. The conditions of germination are the same for both, viz. fresh water bringing oxygen and a relatively lower temperature. Sporangia are undoubtedly the means of rapid multiplication when water is present, be it only a film of water or a saturated atmosphere; for both water and air are necessary for their production (Waterhouse, 1931).

Sporangium

Sporangia form very rapidly on slender emergent hyphae which may be called sporangiophores. As a rule they are less than half the diameter of the hyphae from which they arise (Fig. 3 *a*, *b*). Both the formation of sporangia on a unichasial sympodium and the emission of zoospores from each sporangium in turn as it ripens can be watched and timed. From the initiation of the sporangiophore to the production of the ripe sporangium may be as little as six hours. Fig. 3 *b* is a record of one such observation. Instead of growing forward in length the hypha swells at the tip while at the same time the nuclei continue to divide. This multinucleate sphere becomes ovoid and develops a beak; and it is cut off from the slender sporangiophore by a thin cross-wall. The wall of the sporangium is now differentiated into at least two layers, and at the beak the inner layer is very thick and mucilaginous forming the papilla. Elsewhere the wall is thin, firm and very resistant.

Sporangia vary very much in size according to the conditions under which they are produced. A large one may measure $45 \times 33\mu$ and a small one $28 \times 20\mu$, and abnormally they may be larger or smaller, but a typical one is about $36 \times 28\mu$. In shape, however, they are very constant. The cross diameter is always more than two-thirds the length, including the papilla, which is anything from 3 to 6μ. The number of nuclei in the sporangium varies with the size, but a typical one contains about thirty nuclei evenly distributed in the finely vacuolate protoplasm. There may or may not be an evident sap vacuole in the centre.

If the water in which the sporangium has just developed is still fresh, or better if cooler fresh water be supplied, the protoplasm of the sporangium is divided quickly and completely into uninucleate portions (Fig. 3 *c*). These portions become condensed and round themselves off, giving sap into the interstices so that finally they can move about in this fluid. They gradually assume their characteristic pear shape and develop two lateral flagella. The papilla then absorbs water, and after breaking a thin outer pellicle, it rapidly expands into an evanescent vesicle, which however is not always easy to see. Some of the zoospores are held within it for a fleeting moment and then it bursts and they swim rapidly away, followed more slowly by the remaining zoospores if the water is becoming stale, when the last zoospores take some time to emerge. In fact they may germi-

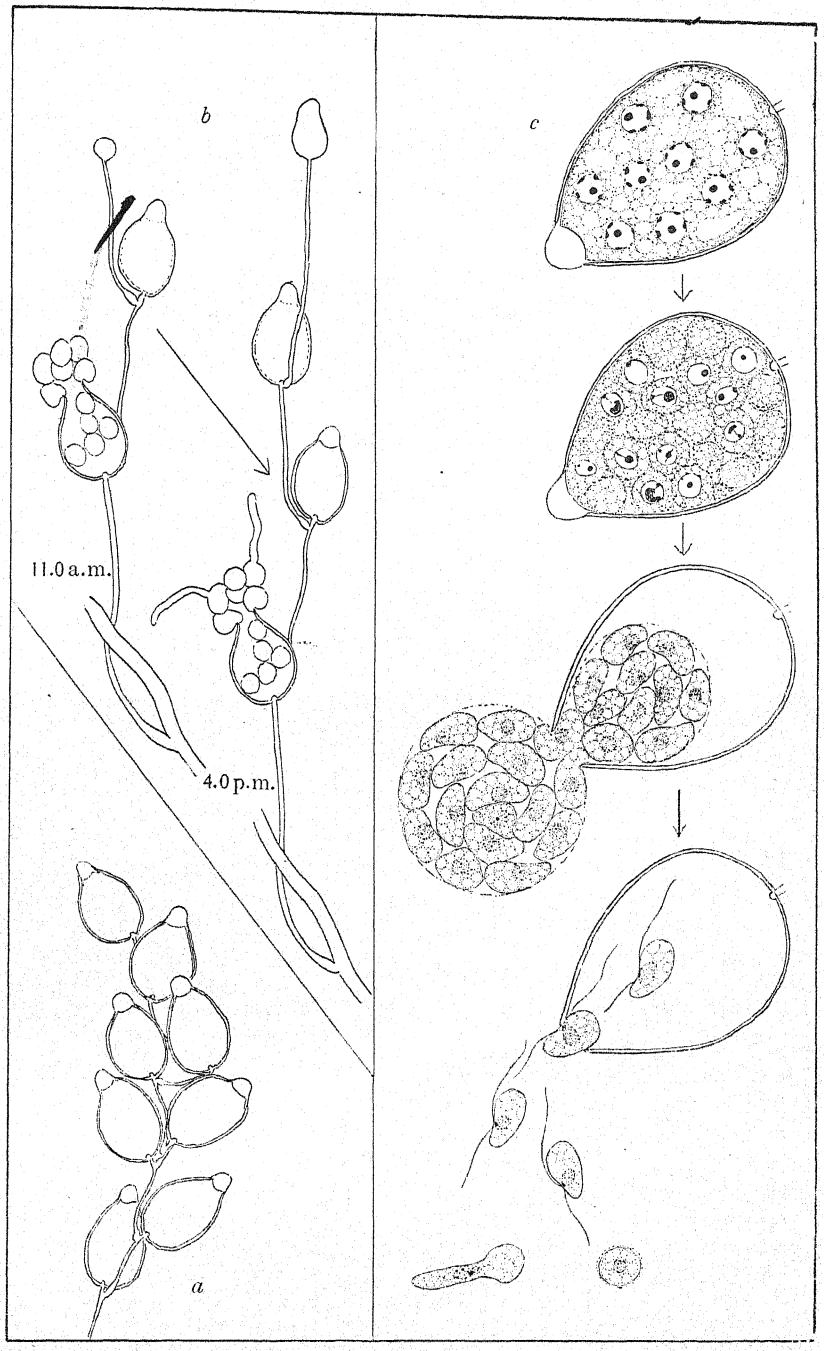


Fig. 3. The sporangiophore, sporangium and zoospore. (*a*) unichasial sympodium of a sporangiophore grown in a moist atmosphere (in outline only. × 400). (*b*) unichasial sympodium of a sporangiophore grown under water, drawn at two stages of its growth, five hours apart. The zoospores have been emitted from the oldest sporangium and have settled at the mouth and begun to germinate there (in outline only. × 400). (*c*) formation of zoospores within a sporangium and their emission in a vesicle developed from the papilla. (Composite drawing, × 1000. The two upper figures, as seen in median longitudinal section.)

nate within the sporangium (Fig. 3 *b*). The emission of the zoospores from the sporangium has been precisely described by Wormald (1919), and the structure of the pear-shaped, uninucleate, biflagellate zoospore of another *Phytophthora* has been illustrated by Cotner (1930) and by Couch (1941). The zoospores swim for about an hour, then settle down, round off and put out a germ tube. This has been called indirect germination of the sporangium. From formation to germination may be only two or three hours, but no doubt the motile phase may be prolonged.

Monospore cultures of zoospores give mycelia as before bearing all the various reproductive organs and thus demonstrate homothallism.

With continual supplies of fresh water, or in a saturated atmosphere, successive sporangia are soon formed by the growth of a hypha from below the basal cross wall, outside the earlier one (Figs. 3, 4). The 'Pythiomorpha' type of proliferation (Blackwell, Waterhouse & Thompson, 1941), where a new sporangium arises from a hypha pushed up into the emptied sporangium, has not been observed in this species even when it is growing in water. The basal plug prevents growth inwards at this point and the new branch of the sporangiophore must grow out immediately below the earlier sporangium pushing it to one side.

The swelling at the base of each branch of the sporangiophore which de Bary (1876) figured for *Phytophthora infestans* and claimed as one of the characters of the genus *Phytophthora* as opposed to *Peronospora* is shown in Fig. 4 *e*.

Conidium

If the sporangium has not given zoospores it ripens into a conidium; and in old cultures in staling media conidia only are developed. Chemical changes in both basal plug and papilla render them less extensible and the protoplasm accumulates fatty reserves in a central globule and deposits a thin layer of cellulose upon the wall. Once the conidium has entered upon these maturation changes it seems unable to produce zoospores under any circumstances. It must germinate by a germ tube. The germ tube, however, may grow straight through the still soft papilla and emerge apically. It is multinucleate from the first for into it pass the nuclei of the multinucleate conidium.

Resting conidium

If kept moderately dry the conidium may rest for months, the papilla becoming harder and the wall layer of reserves thicker. Accordingly when water is supplied the germ tube cannot always emerge through it; instead the papilla must be pushed aside and an exit forced about its base. There may be more than one germ tube each forcing a separate exit. In an old culture chains of conidia are found all empty except for the last one produced, as though from time to time enough water for germination has been available (water of condensation perhaps caused by a fall in temperature) followed immediately by conditions that encourage conidial formation, e.g. a drying or staling medium. As a certain amount of reserve has been used up in the short period of growth, each newly formed conidium is rather smaller than the previous one (Fig. 2 *c*). Given the right conditions for vegetative

growth a conidium may give rise to vegetative hyphae, or to a sporangium or even to an oogonium with antheridium (Fig. 4).

Chlamydospore

A similar resting spore and one that cannot be sharply distinguished from the resting conidium is called a chlamydospore. Chlamydospores appear in great abundance in an old culture that has been subjected to wide extremes of temperature. They are usually terminal, rarely intercalary. They vary in size and in number of nuclei even more than sporangia and conidia vary. A typical chlamydospore differs from a typical conidium in being quite spherical, in having no papilla and in having a thicker layer of reserves inside the wall in addition to the oil reserves. It germinates fairly readily by a multinucleate germ-tube.

The chlamydospore is so frequently confused with the oospore that the following distinguishing features may usefully be stressed. It is not developed free of the hyphal wall as is the oospore within its oogonium, to which is usually conspicuously attached the antheridium; it stores oil but never in a single large oil globule; between crossed nicols the wall is very much brighter than the oospore, and this is the surest method of distinguishing them.

Oogonia and antheridia

The oogonia and antheridia are initiated on adjoining lateral branches either submerged or emergent. They are first observed as a rule at the stage shown in Figs. 5 *a* and 4 *a*, *b*, where the tips of these neighbouring hyphae have met and expanded into two equal-sized, multinucleate spherical heads. Soon one swollen hyphal tip becomes larger than the other with more nuclei and can then be recognized as the oogonial initial; the other, the antheridial initial, shows very little further enlargement and so comes to lie on the neck of the swelling oogonium. It is not known what determines which of these two organs shall be the oogonium. It is observed, however, that the hypha bearing the antheridium is usually more slender than that bearing the oogonium, which suggests that available food may be a determining factor; as, however, the difference in size of the hyphae is more marked in the later stages, this may be an effect rather than the cause. It has been observed, too, that the antheridial branch is borne nearer to the growing point of the hypha that has produced the pair of lateral branches (Fig. 4 *a*, *b*).

The two organs are soon firmly attached by their walls, as with a sticky secretion, so that any injury serves only to tear them from their hyphal stalks, never from one another. They assume their maximum size in an hour or so when the diameter of the oogonium varies from 25 to 40μ (generally about 33μ), and the longest diameter of the antheridium from 12 to 15μ. The nuclei of each swelling tip divide two or three times so that each organ finally contains a number of nuclei: the oogonium rather less than thirty and the antheridium usually less than ten (Fig. 5 *b*). In this condition they may be found in great numbers between 8.0 and 10.0 a.m. on a mycelium that the previous night showed no signs of reproductive

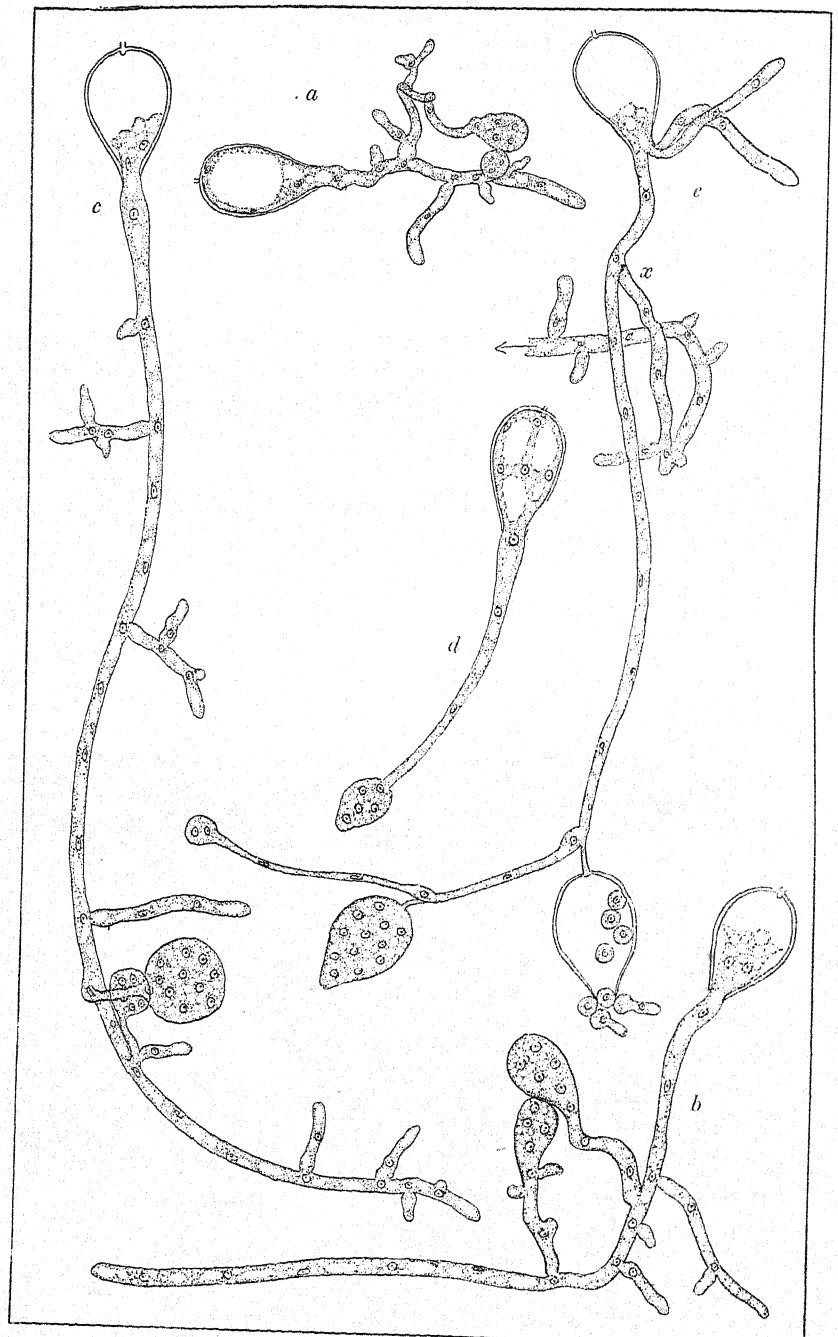


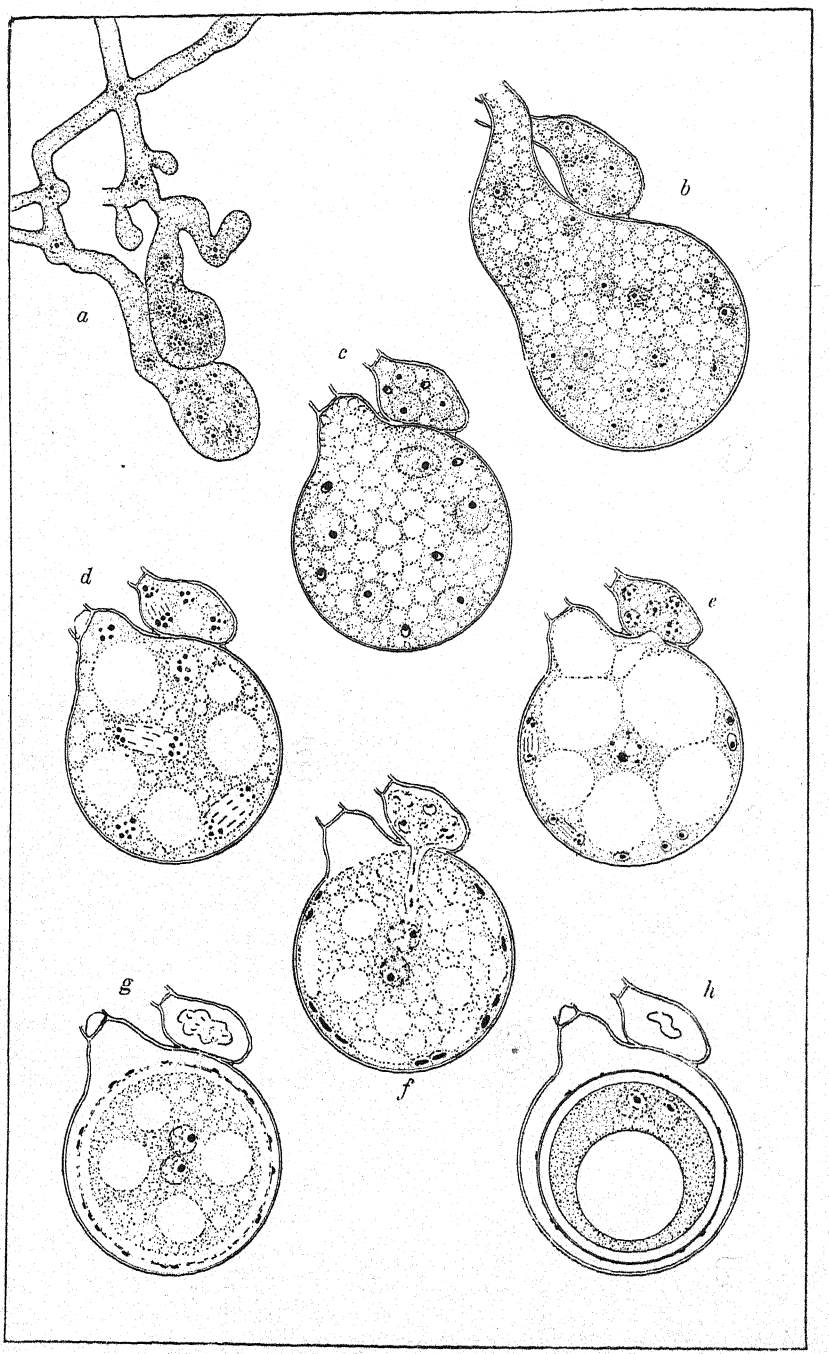
Fig. 4. The germinating conidium. ×450. All these conidia and many others were found germinating in a seven-months-old culture that had been soaked for two days in dilute apple juice. Some conidia had given mycelia without reproductive organs. The age of the conidia is not known. (*a*), (*b*) and (*c*) had germinated to give oogonium and antheridium in two days. (*a*) and (*b*) have paragynous antheridia and (*c*) an amphigynous antheridium. (*d*) had germinated to give a sporangium in two days. (*e*) from the same culture after four days was found to have three germ tubes: the longest of these had forked to give a branch bearing an oogonium and antheridium which later died at the fork (*x*), and another branch which became a sporangiophore.

organs. After a septum has formed cutting off each reproductive organ from its parent hypha (and the antheridial septum is always formed first) the protoplasm becomes more vacuolate, and the nuclei are reduced in number (the presence of deeply stainable bodies in the protoplasm suggests that some have degenerated) (Fig. 5 *c*). In the forenoon of the same day the majority of the oogonia have eight or nine large resting nuclei disposed equidistantly from one another with large sap vacuoles in between, and the majority of the antheridia have four or five equally large and well-defined nuclei (Fig. 5 *c*). About noon they all divide simultaneously (Fig. 5 *d*). This process is very conspicuous, rather drawn out so that stages can therefore readily be fixed in the late forenoon. The eight or more nuclei of the antheridium and the sixteen or more nuclei of the oogonium now arrange themselves evenly throughout the vacuolate protoplasm, but in the oogonium a nucleus in the centre gradually assumes dominance and by the next morning there is a mass of ooplasm with one central nucleus which may be termed the oosphere, delimited from the thin periplasm with the rest of the nuclei (Fig. 5 *e*). The fertilization tube which appears to be an extension of the fused wall of oogonium and antheridium, bent by pressure first towards the antheridium (the so-called receptive papilla) and then towards the oogonium (the fertilization tube), passes right into the ooplasm and finally gives way, liberating one nucleus which fertilizes the oosphere (Fig. 5*f*).

On occasion a few amphigynous antheridia are formed in some transfers, perhaps 1 % of the whole; but, as Murphy (1918) has shown, this in no way affects the normal course of fertilization.

The oospore

Immediately after the entry of the antheridial nucleus into the ooplasm, a thin limiting membrane forms and the young bi-nucleate oospore is delimited within the periplasm (Fig. 5 *g*). Material fixed between 7.0 and 9.0 a.m. shows this stage and sometimes, though infrequently, the fertilization tube, which is evidently of short duration. Material fixed and stained about noon with picro-nigrosin shows two to three dozen black dots distributed mostly in pairs, upon the still thin wall of the young oospore. They are presumably the nuclei of the periplasm after their last division before final degeneration. This thin nucleate protoplasm becomes closely applied to the oospore membrane and with it forms the exospore which therefore is entirely of protoplasmic origin. It immediately becomes very resistant, and subsequently the endospore accumulates upon the inner face of the membrane of the oospore, as a thick storage layer with a basis of cellulose and protein. Within the protoplasm numerous globules of oil form and later fuse into the characteristic excentric oil globule (Fig. 5 *h*). In the course of a month, and the period is longer at low temperature (5° C.), the nuclei fuse. Both the paired nuclei and later the fusion nucleus appear in a clear area which on application of 1 % osmic acid gives a sharp black reaction. This indicates that oil is in close association with the nuclei and suggests the possibility of a plastid which forms and divides with



Text-fig. 5.

the nucleus; but no definite body has so far been demonstrated by the stains and reagents used.

The protoplasm and nuclei left behind in the antheridium degenerate into an oily mass, and the antheridium rarely becomes quite empty. But it remains fixed to the oogonium wall until after the oospore germinates. It is rare to find an oogonium from which the antheridium has broken away. Such a rarity is, however, shown in Fig. 7 *a*.

During oospore formation the hyphae bearing the firmly attached oogonium and antheridium have grown and twisted together and thrown out other branches so that the whole is a tangle, and it is impossible to trace the origin of the two fertile branches. The oogonial and antheridial walls remain colourless and transparent but they have matured in different ways. In chlor-zinc-iodide the oogonium wall turns a violet blue and the antheridium a claret colour. With a more exact microchemical technique, it has been demonstrated that both walls have a basis of cellulose which is impregnated with substances that are different in the two organs. The septum across the oogonial stalk becomes thickly plugged on the side away from the oogonium with a substance that may be callose. It turns a striking greenish blue with lacmoid (resorcin blue).

The oospore now enters upon what may be months of dormancy. The dormant period may be said to begin when the oospore is at its minimum diameter lying loosely in its oogonial wall. The exospore is thin, smooth and transparent, built of pectic substances, most resistant and almost impermeable. Few stains can penetrate it, though spores left in aceto-carmine for a week show a faintly pink fusion nucleus. The endospore is composed of cellulose, protein and possibly other reserve substances and is at its thickest (2μ). The excentric oil globule is composed of fats in a high state of saturation, and not readily blackened by osmic acid. The colloids of the protoplasm hold a minimum of imbibed water and the protoplasm appears homogeneous, colourless and condensed. But the paired nuclei have not fused.

The first stage of dormancy, then, is this delay of fusion of the nuclei. The fusion nucleus when formed three, four or more weeks later continues to turn sharply black in osmic acid and the protoplasm to remain colourless.

It is important at this point to realize that each oospore is an independent product. It matures in its own time, with its own period of delay in fusion

Legend to Text-figure 5.

Fig. 5. Development of oogonium, antheridium and oospore. (*a*) initials of oogonium and antheridium (see also Fig. 4). (*b*) oogonium and antheridium grown to full size: the oogonium has about twenty-four nuclei and the antheridium about nine. (*c*) development of a septum at the base of each, and degeneration of some nuclei in each until the oogonium has eight or nine nuclei and the antheridium four or five. (*d*) a simultaneous division of the surviving nuclei in oogonium and antheridium. The protoplasm has large vacuoles. (*e*) separation of ooplasm from periplasm. Nuclei in division in periplasm prior to degeneration. Oogonium presses into antheridium. (*f*) entry of one antheridial nucleus by a fertilization tube. The protoplasm and remaining nuclei of the antheridium degenerate. (*g*) development of oospore wall. (*h*) oospore enters on its dormant period with exospore formed from dead periplasm; endospore (of cellulose, protein, etc.) deposited upon it, and paired nuclei in association but not yet fused. (*a*)–(*h*) are composite drawings of eight stages in sequence. × 1000.

of the paired nuclei, and its own individual deposit of reserves. One is reminded of this fact when watching oospores germinate: one at a time and never all together. The same external conditions have a different effect on different oospores.

Germination of the oospore

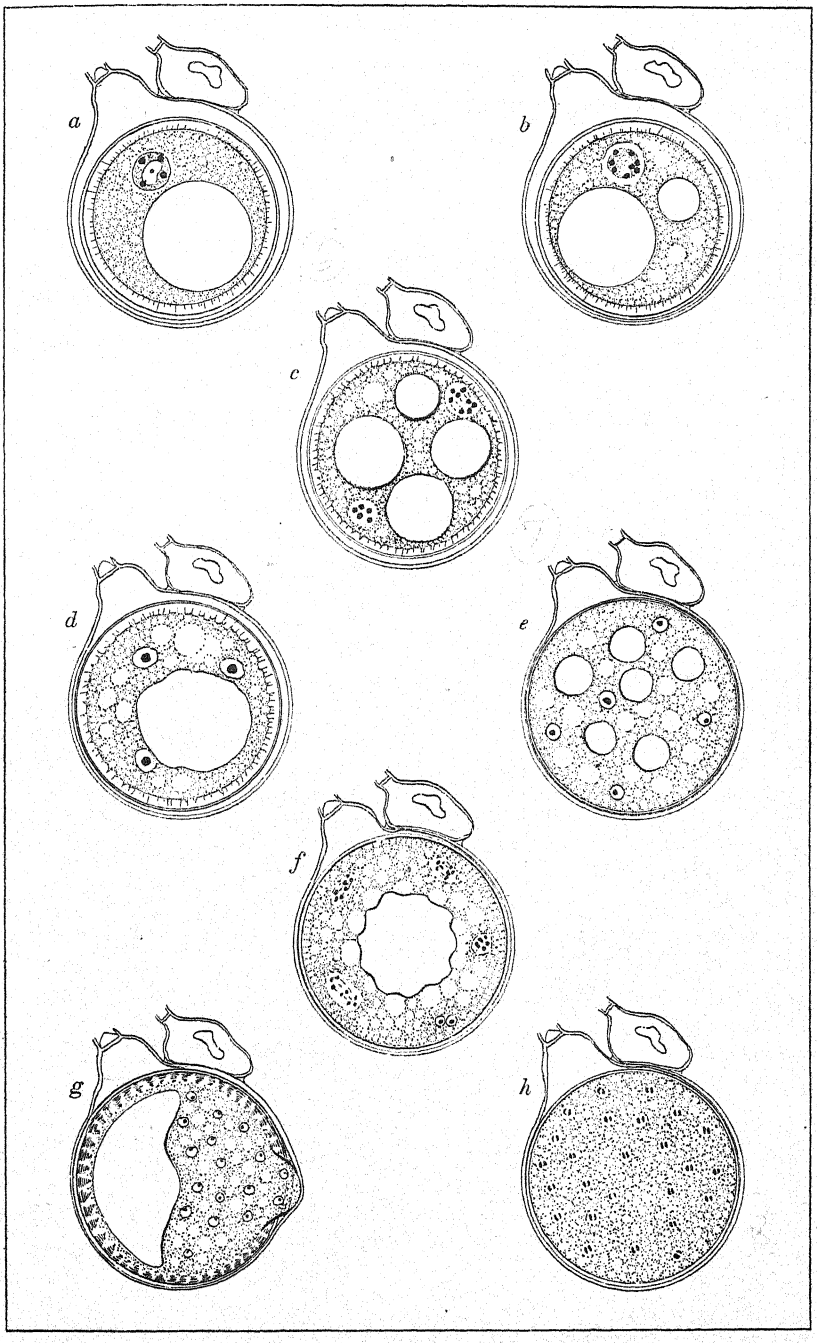
Before it can be germinated, the oospore requires a further period of dormancy. This is comparable to the period known as the 'after-ripening' of seeds. This period at laboratory temperature is a further six or seven months, but at a temperature just above freezing point it can be speeded up to one or two months. And when 'after-ripening' is completed the oospore may continue to lie dormant for many months more, if it is not germinated. The oospores during this threefold dormancy must be kept comparatively moist. Desiccation means death. It seems that inconceivably slow metabolic changes are proceeding in the living protoplasm and its included reserves. There cannot be an utter cessation of metabolism without death. It is difficult therefore to say when dormancy ends and preparation for germination begins.

Oospores prepared for germination have a characteristic dull, soft, granular appearance: the finely vacuolate protoplasm showing clearly through the transparent walls. They are very striking by contrast with dead spores which may be found lying among them and which look bright, hard and 'glassy'. The changes that have taken place in the living oospore are these. The spore has expanded so that it now almost entirely fills the oogonial cavity. Evidently the exospore has stretched, but not the oogonial wall. The oil globule once again turns black on application of osmic acid, but the action takes place at the surface of the globule and unevenly, giving smaller or larger black areas. The globule breaks up into smaller ones. Oospores at this stage may contain anything from one to ten globules and soon the latter disappear altogether as though mixed into the protoplasm which is now more ample and finely vacuolate. After the small oil globules have formed but before the oil is incorporated into the protoplasm the absorption of the endospore begins. This may take place as rapidly as it was earlier built up, or it may appear eroded as though half digested by enzyme action. Fine radiating passages in this wall suggest that the reserves of cellulose, protein, etc. are being digested at different rates.

While the succession of changes in the oil reserve and the endospore is proceeding concurrently but independently, the fusion nucleus is subdividing and thus initiating a succession of independent changes of its own.

Legend to Text-figure 6.

Fig. 6. The oospore towards the end of dormancy, between 'after-ripening' and germination. (*a*) and (*b*) fusion nucleus in division, oil globule breaking up, endospore becoming eroded. (*c*) second nuclear division, oil globule broken up. (*d*) four-nucleate stage, oil globule dispersing gradually. (*e*) eight-nucleate stage, oil globules further subdivided, endospore almost completely absorbed. (*f*) fourth nuclear division, oil globule still single, endospore almost completely absorbed. (*g*) about thirty-two nuclei, oil globule still single, endospore not yet absorbed, germ tube through exospore but not yet through oogonium wall. (*h*) sixth nuclear division, nuclei very small, all reserves absorbed into protoplasm but germ tube not yet formed. (*a*)–(*h*) are composite drawings of median longitudinal sections (× 1000) not representing a sequence of stages.



Text-fig. 6.

The first and second divisions are conspicuous and take place before there has been any great digestion of the reserves. Three drawings of these large dividing nuclei are shown in Fig. 6 *a*, *b*, *c*. Prior to emission of the germ tube further divisions (from one to four) have taken place so that the germinating oospore may have eight large nuclei or very many small ones.

A reversal of the stages passed through in the formation of the oospore within the oogonium has taken place. The oospore now almost fills the oogonial cavity; its protoplasm, though without obvious food reserves, is active, and it contains many relatively small nuclei.

The last stage before emission is the piercing of the thin transparent resistant walls: exospore and oogonial wall. Here again are two independent processes, for it is often observed that the germ tube has forced its way through the oospore wall and has then wound its way about within the oogonial wall unable to penetrate it (Fig. 7 *d*, *e*). It appears as if the oospore wall, which is extensible, is pressed thin at one point until it gives way, but that the oogonial wall which is not extensible is cracked.

The germ tube may be emitted before or after all the oil is absorbed into the protoplasm, and before or after the endospore is entirely digested.

The germ tube, it seems, may be emitted anywhere: presumably at the weakest point. There is no germ pore. Further germ tubes may be emitted at other points but not as a rule if the first is making vigorous growth (Fig. 7 *f*, *g*).

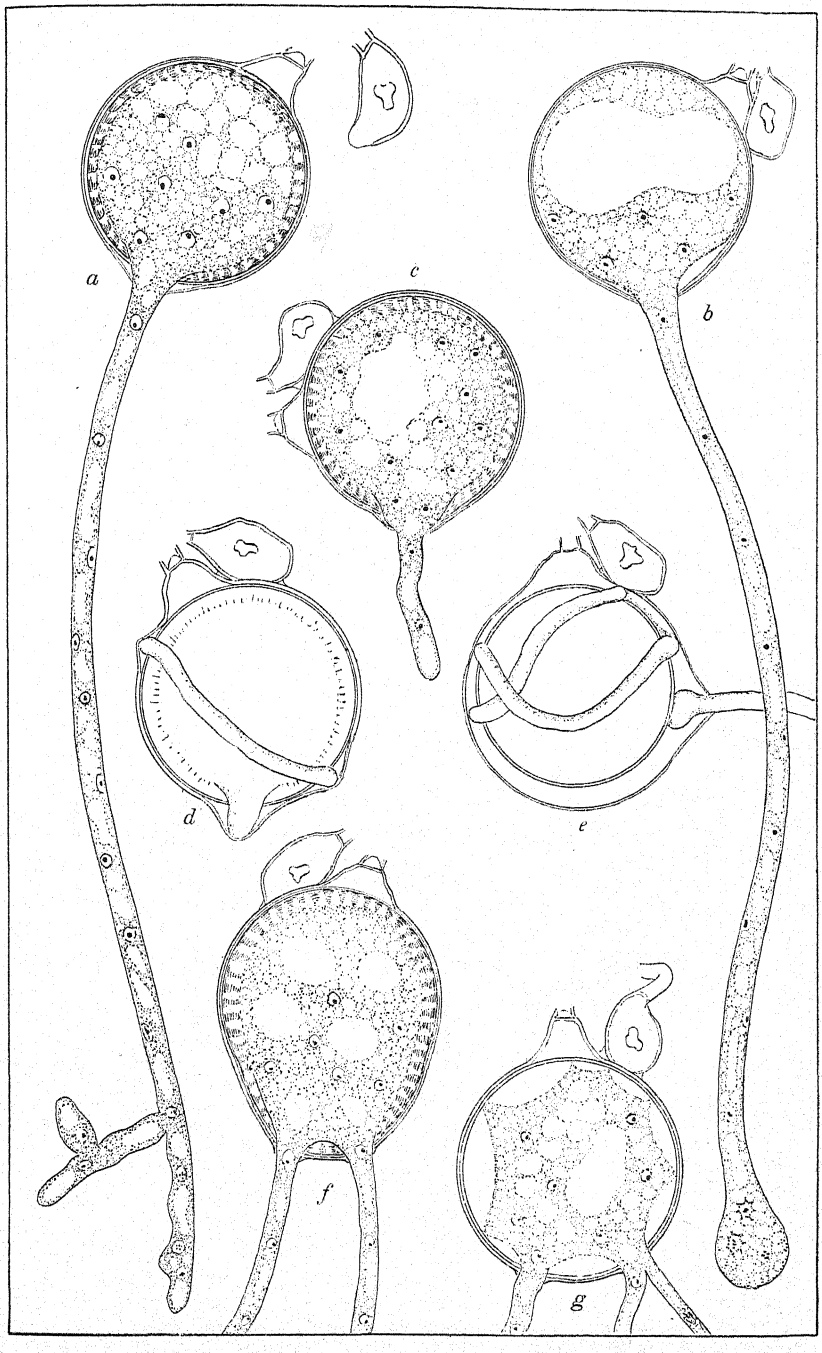
Single germinating oospores isolated and transferred to fresh media give mycelia as before, bearing all the various reproductive organs, and thus demonstrate homothallism.

The precise conditions that ensure germination of the oospore lie within narrow limits. Moreover at any stage during the absorption of the endospore, a secondary dormancy may set in more resistant even than before and more difficult to break. The oospores then may lie for months waiting for the magic touch that originates the emission of the germ tube. Among a collection of oospores, thin-walled, multinucleate, with reserves absorbed into the protoplasm, obviously just primed for germination, only occasional ones are found germinating. The extremely resistant double envelope of exospore and oogonial wall will not give way.

This is a very difficult step and it may be that there is no magic touch

Legend to Text-figure 7.

Fig. 7. The germinating oospore. (*a*) has germinated to give a mycelium direct. (Note the detached antheridium.) (*b*) has germinated to give a sporangium. (*a*)–(*e*) have each produced one germ tube, (*f*) two germ tubes and (*g*) three germ tubes. (*a*), (*c*), (*d*), (*f*) have germinated before the endospore is absorbed, (*b*), (*e*) and (*g*) after complete absorption of the endospore. (*d*) and (*e*) have germ tubes which penetrated with difficulty after winding about between exospore and oogonial wall. (*f*) has been pulled lengthwise by the growth of two germ tubes in one direction and so become ovoid in form. N.B. (1) the extreme resistance and inelasticity of the oogonial wall and the persistence of the antheridial wall. (2) the thin resistant exospore. (3) that the endospore may be digested before or during germination. (4) that the oil globule may be broken up into smaller ones or gradually absorbed before or during germination. (5) the germ tubes may be one or more. (6) the germ tube may give rise to a mycelium direct or to a sporangium. (7) the antheridium very rarely breaks away. (*a*), (*b*), (*c*), (*f*) and (*g*) are composite drawings of median longitudinal sections. × 1000. (*d*) and (*e*) are outline drawings of oospores in surface view as seen through the transparent oogonial wall. × 1000.



Text-fig. 7.

for oospores in the mass: for each oospore makes its own cracks, has formed its own growth substances, produces as a result of its own respiration its own changes in acidity, makes its own peculiar response to conditions outside (e.g. to an alkaline medium produced by bacterial colonies), because each is a slightly differently organized unit. But what better fortune could any parasite have than that its resting spores should not all germinate in one and the same set of conditions?

My grateful thanks are here offered to Mr R. J. Tabor, of the Imperial College of Science, London, who supplied the original culture and advised me that the species was worth a careful study; to Sir Edwin J. Butler and to Mr Ashby, some-time Directors of the Imperial Mycological Institute, Kew, for kind encouragement in the work; to Mr William Horton of Liverpool University, who in the early days of the investigation kindly undertook some of the labour of embedding fixed material and cutting sections; to Dr Margaret Madge of this College, and to Mr Edmund Mason, Mycologist, Imperial Mycological Institute, for their ever-ready help and criticism at all times, and for reading the manuscript; and especially to Miss Grace Waterhouse, of this College, for information, as yet unpublished, from her notes on the microchemistry of the walls, for much useful criticism, and for reading the manuscript.

Summary

An account is given of the life history of *Phytophthora Cactorum* (Leb. & Cohn) Schroet., a paragynous, homothallic species.

The mycelium and reproductive spores in their development and germination are described as under:

The mycelium: its vegetative growth and form and its perennation.

The sporangium, conidium, resting conidium, chlamydospore: their interrelationships, development and germination.

The oogonium and antheridium: fertilization.

The oospore: its dormancy and germination.

REFERENCES

Bary, A. de (1876). Researches into the nature of the potato-fungus *Phytophthora infestans*. *J. Roy. Agric. Soc. England*, S. 2, xii, 239–69. Reprinted in *J. Bot.* (*London*), xiv (N.S. v), 105–54.

Bary, A. de (1881). Zur Kenntniss der Peronosporeen. *Bot. Ztg*, xxxix, 521–625.

Blackwell, E. M. (1935). Germination of resting fungal spores. *Nature*, cxxxv, 546.

Blackwell, E. M. & Waterhouse, G. M. (1931). Spores and spore germination in the Genus *Phytophthora*. *Trans. Brit. myc. Soc.* xv, 294–321.

Blackwell, E. M., Waterhouse, G. M. & Thompson, M. V. (1941). The invalidity of the genus *Pythiomorpha*. *Trans. Brit. myc. Soc.* xxv, 148–65.

Cotner, F. B. (1930). The development of the zoöspores in the Oömycetes at optimum temperatures and the cytology of their active stages. *Amer. J. Bot.* xvii, 511–46.

Couch, J. N. (1941). The structure and action of the cilia in some aquatic Phycomycetes. *Amer. J. Bot.* xxviii, 704–13.

LAFFERTY, H. A. & PETHYBRIDGE, G. H. (1922). On a *Phytophthora* parasitic on apples which has both amphigynous and paragynous antheridia; and on allied species which show the same phenomenon. *Sci. Proc. Roy. Dublin Soc.* XVII, N.S. 4, 29–43.

LEBERT, H. & COHN, FERDINAND (1871). Ueber die Fäule der Cactusstämme. *Beitr. Biol. Pflanz.* I, Heft 1, 51–7.

MURPHY, P. A. (1918). The morphology and cytology of the sexual organs of *Phytophthora erythroseptica* Pethyb. *Ann. Bot.* XXXII, 115–52.

PETHYBRIDGE, G. H. (1913). On the rotting of potato tubers by a new species of *Phytophthora* having a method of sexual reproduction hitherto undescribed. *Sci. Proc. Roy. Dublin Soc.* XIII, N.S. 35, 529–65.

PETHYBRIDGE, G. H. (1914). Further observations on *Phytophthora erythroseptica* Pethyb., and on the disease produced by it in the potato plant. *Sci. Proc. Roy. Dublin Soc.* XIV, N.S. 10, 179–98.

SCHROETER, J. (1886). In *Pilze Kryptogamen-Flora* von Schlesien von Prof. Dr Ferdinand Cohn, III, i, 236 (1885–9).

TUCKER, C. M. (1931). Taxonomy of the genus *Phytophthora* de Bary. *Res. Bull. Miss. Agric. Exp. Sta.* no. 153, 208 pp.

TUCKER, C. M. (1933). The distribution of the genus *Phytophthora*. *Res. Bull. Miss. Agric. Exp. Sta.* no. 184, 80 pp.

WATERHOUSE, G. M. (1931). The production of conidia in the genus *Phytophthora*. *Trans. Brit. myc. Soc.* XV, 311–21.

WORMALD, H. (1919). A *Phytophthora* rot of pears and apples. *Ann. appl. Biol.* VI, 89–100.

(*Accepted for publication* 1 *August* 1942)

FUNGUS FORAY, ROYAL HOLLOWAY COLLEGE

25 and 26 September 1942

G. C. AINSWORTH

On Friday and Saturday, 25 and 26 September 1942, a foray was held in the Englefield Green district with headquarters, by kind permission of the Principal, at the Royal Holloway College where Miss E. M. Blackwell had generously placed the facilities of the botanical laboratories at the Society's disposal. Among a number of interesting exhibits displayed in the museum were *Phytophthora infestans* (Mont.) de Bary on *Lycium halimifolium* from Dr G. H. Pethybridge, *Cercospora depazeoides* (Desm.) Sacc. on elder from Dr A. Smith, photographs and drawings by Miss Blackwell, and a much admired series of some 200 sheets of water colour drawings by Miss M. E. Notley of the larger fungi of the neighbourhood.

About twenty-five members and friends assembled on the Friday morning and after lunch set out on foot for the Clockcase wood which was worked for about an hour. The party then proceeded to Cooper's Hill, at one time the Royal Indian Engineering College where Marshall Ward was stationed. Here tea was taken and the grounds explored. In the evening, Mr J. Ramsbottom gave a lecture on Edible Fungi to residents of Windsor Great Park, and, at the College, there was an interesting discussion on the mycological aspects of Mr W. C. Moore's Presidential Address, which culminated in a resolution to Council (see p. 91). The next day, a larger party made a whole-day excursion to the Bishop's Gate area of Windsor Forest.

The rain of the previous week had not nullified the effect of the prolonged dry weather and agarics were not plentiful although commoner species were in fair variety. In the Clockcase wood a specimen identified as *Hydnum zonatum* Batsch. ex Fr. attracted some attention and one enthusiastic mycophagist made a large and miscellaneous collection of edible forms. At Cooper's Hill a number of interesting micro-fungi were found including *Cercospora depazeoides* on elder and *Cristulariella depraedans* (Cooke) v. Höhn., on sycamore. The pathologists added records from the College garden and Dr C. T. Ingold found nine species of aquatic Hyphomycetes on decaying leaves of alder and oak from a pond near the Botany Building. On Sunday morning a fine specimen of *Strobilomyces strobilaceus* (Scop. ex Fr.) Berk. was brought in from Farnham. Mycetozoa and Lichenes were each represented by about a dozen species in a final list (filed for reference among the Society's records) of approximately 225 species.

PROCEEDINGS

Joint Meeting of the British Mycological Society and the Association of Applied Biologists, held at the London School of Hygiene and Tropical Medicine, 9 October 1942.

In the morning the Chair was taken by the President of the British Mycological Society, Miss E. M. Blackwell, M.Sc.; in the afternoon by the President of the Association of Applied Biologists, Dr H. Martin.

The programme, which had been arranged by the Plant Pathology Committee, was devoted to a Discussion on Potato Virus Diseases.

[For a detailed account of this meeting see *Ann. appl. Biol.* xxx, 1943.]

Meeting held in the University Department of Botany, Oxford, 14 November 1942.

The President, Miss E. M. Blackwell, M.Sc., in the Chair.

W. R. Day. Butt-rot in conifers and soil conditions.
W. H. Wilkins. The production of bacteriostatic substances by fungi.
Professor H. W. Florey. Moulds and medicine.
S. P. Wiltshire. A few thoughts on the situation in medical mycology.

ANNUAL GENERAL MEETING

12 December 1942

The Annual General Meeting was held in the rooms of the Linnean Society of London at 12 noon on Saturday, 12 December 1942, with the President, Miss E. M. Blackwell, M.Sc., in the Chair.

After the Minutes had been read and confirmed, the President recorded with deep regret the deaths of three members, Mr F. W. Hildyard, Mr J. W. Haig Johnson, and Mr Rupert Smith, and announced that Mrs Catharine Watts had generously presented Mr F. W. Hildyard's set of the *Transactions* to the Society for the Society's use. Council had decided that the set, which was complete, should be bound, placed in the Secretary's charge, and kept up to date and that volumes might be borrowed by members resident in the British Isles.

The President then briefly reviewed the past year and drew attention to the discussions by all sections of the Society of Mr Moore's Presidential Address. As a result of a memorandum from the Plant Pathology Committee, Council had invited the Association of Applied Biologists to set up a joint committee 'to consider means by which the future development of the study and practice of plant pathology in this country can best be furthered' and this invitation had been accepted. In response to a resolution from a meeting held during the September foray, Council had appointed a sub-committee to study the question of systematic mycology in this country and had, on the recommendation of this sub-committee, set up a small Foray Committee to organize the Society's field work.

Mr J. Ramsbottom was, at his own request, not seeking re-election as an editor and on a motion from the Chair a very hearty vote of thanks to Mr Ramsbottom for his twenty-four years service as an editor was passed with acclamation.

The President concluded by expressing the Society's appreciation of the Linnean Society's kindness in again providing facilities for the Society's meetings.

Mr A. A. Pearson next submitted the Treasurer's Statement. He said that the general financial situation was still satisfactory. The Accounts were adopted on the motion of Mr F. G. Gould who expressed the Society's pleasure at Mr Pearson's recovery from his recent illness.

Dr S. P. Wiltshire was proposed from the Chair as Council's nominee for the Presidency for 1943 and he was elected unanimously. In addition to the retiring President and her predecessor in office, Mr W. C. Moore, Dr C. G. C. Chesters was elected as a Vice-President.

The other Officers, *General Secretary*, Mr J. Ramsbottom, *Secretary*, Dr G. C. Ainsworth, *Treasurer*, Mr A. A. Pearson, and *Editors*, Dr B. Barnes and Dr H. Wormald, were re-elected and Mr E. A. Ellis, Dr C. T. Ingold and Dr J. H. Western were elected as members of Council in place of Dr G. Deacon, Dr P. H. Gregory and Mr J. S. Hughes.

The Plant Pathology Committee's nominations, Mr F. C. Bawden, Mr A. Beaumont, and Mr C. J. Hickman to replace Mr S. D. Garrett, Dr P. H. Gregory, and Dr T. H. Harrison, were accepted.

After two new members had been elected, making twenty for the year, the General Secretary briefly outlined Council's tentative proposals for 1943 and the date for the next Annual General Meeting was fixed for 11 December 1943.

The meeting then adjourned until 2 o'clock when the President gave her address 'On germinating the oospores of *Phytophthora Cactorum*' after which Mr Ramsbottom moved a vote of thanks to Miss Blackwell.

G. C. AINSWORTH

RECEIPTS AND PAYMENTS

for the Year ending 30 June 1942

1941		£	s.	d.
1 July	Balance brought forward... ...	564	14	5
1942				
30 June	Subscriptions to date	285	15	10
	Gifts to Printing Fund	4	18	3
	Profit from Sale of:			
	British Basidiomycetæ	3	16	9
	Diseases of British Grasses ...	15	6	5
	Deposit Interest	2	8	1
	War Loan Interest	17	10	0
		£894	9	9

1942		£	s.	d.
30 June	Cambridge University Press, Cost of printing *Diseases of British Grasses*	101	2	11
	Postages, etc.			
	Treasurer	2	16	11
	Secretary	2	14	11
	Sec. Plant Pathology Committee	1	6	6
	Editor	2	1	6
	Sundry Printing	8	2	11
	Fees of Meetings		10	0
	Purchase of *Transactions*	2	3	9
	Balance in bank	773	10	4
		£894	9	9

CAPITAL ACCOUNT—*Robinson Bequest*, £50; *Cheesman Fund*, £150; *Printing Fund*, £300 } *invested in* 3½% *War Loan*

A. A. PEARSON, Hon. Treasurer

Examined and found correct, F. G. GOULD
3 *August* 1942

PRESIDENTIAL ADDRESS

ON GERMINATING THE OOSPORES OF *PHYTOPHTHORA CACTORUM*

By ELIZABETH BLACKWELL, M.Sc., F.L.S.

Some spores germinate readily. One might say embarrassingly readily, thinking of the ubiquitous germlings from *Penicillium* conidia in the laboratory and from *Botrytis* conidia out of doors. For these it seems there is no obstacle to be overcome and there is no delay. The spores swell with imbibed water and the wall is stretched in one or more directions to give germ tubes. And this is so, even if some weeks of dormancy have been forced upon these air-borne spores by drought or a low temperature. The food reserves, and any growth-promoting substances there may be, are at once available; the wall at once permits the exit of a germ tube.

There are some spores which not only can but must germinate at once. Zoospores of water moulds as a rule germinate a few minutes after they are produced. The sporidia of plant rusts likewise must germinate at once or perish.

There are other spores which do not germinate readily: some not until months have elapsed, even years. They are called resting spores, and their common characteristic is that they needs must pass through a period of dormancy before germination. The exact nature of dormancy is not known; but dormancy of spores, like dormancy of seeds, is not a simple state. The early period of dormancy includes stages of maturation: e.g. deposition of reserves, wall formation, sometimes nuclear fusion; and while the spore is immature it does not, normally, germinate. The middle period includes changes in the protoplast and particularly in the reserves both within the protoplast and upon the inner face of the wall; perhaps changes in hydrogen-ion concentration affecting enzyme action and metabolism. The spore cannot germinate until this so-called 'after-ripening' is complete. The last period includes preparation for germination, e.g. assimilation of reserves, activation of growth-promoting substances, the breaking down of an impermeable wall, nuclear division; and the final step is the emission of the germ tube. These periods are of different lengths in different spores, and in any one spore they may be shortened or lengthened by external conditions during storage. The middle period, the period of 'after-ripening', is not always obvious. Some spores seem to pass steeply to the peak of maturation and then immediately begin the preparation for germination. For others there seems to be no 'peak' but rather a long plateau of after-ripening in the passage of which the spore, though mature, cannot proceed at once to germination. The teleutospores of *Puccinia malvacearum* and *P. graminis* differ not in the length of time they can remain dormant but in the length of time they must. The former will germinate almost at once: the latter not for some months except after special treatment. As Duggar once

expressed it: 'they need all the changes of the winter months.' It is this 'needs must' that is so surprising. Enforced dormancy one can, to a certain extent, understand. Whatever dormancy may be, it cannot be entirely suspended in these naturally dormant spores, but it can be shortened, and the various agents that have been used, as we say, 'to encourage germination', do shorten or 'break' dormancy one way or another.

Before proceeding to a review of these agents, and at the risk of stating the obvious, I would remind you that however much spores may be controlled in germination, they keep their own individual way of emitting a germ tube. In other words, they are genetically different, and this is dependent on the nuclear state which is beyond control of the agents about to be reviewed. This genetical difference is very strikingly brought home to one when observing uredospores and sporidia of *Coleosporium Tussilaginis* collected upon the same coverslip over an inverted van Tieghem cell. These golden spores, superficially not unlike, though the former is binucleate and the latter uninucleate, germinate in quite different ways: the former putting out two or three narrow germ tubes through germ pores, the latter swelling out into a single wide tube into which all the protoplasm at once passes. Another familiar example of the individuality of germinating spores is afforded by the conidia and ascospores of *Eurotium herbariorum*. The spiny conidia put out one or two germ tubes, while the ascospores form a germ tube as an expansion of the thinner belt which pushes aside the two lateral flanges. It is important to remember these genetical differences and to admit that there are limits to what one can do in controlling spore germination. No doubt there are limits too set by physiological differences of different spore types.

The agents that have been proved effective in germination of spores are those which have been used to break the dormancy of seeds, viz. a raising or lowering of the temperature, alternation of high and low temperatures, alternation of drying and wetting, light, 'nutrient solutions', 'volatile substances', the presence of the host of a parasite, some one common volatile substance generated by the presence of other living organisms in the same medium, carbon dioxide, bacteria, alkalinity, acidity, change of hydrogen-ion concentration, ionic content of the solution, and last but not least time.

A consideration of these various 'agents that encourage germination' leads one to suspect that the action is sometimes mechanical, sometimes chemical: that it may be upon the impermeable wall, upon the reserves or directly upon the living protoplast. For instance, a raising or lowering of temperature may initiate chemical changes in the reserves, or may have an indirect effect in producing by-products of decomposition which are themselves the activating agents. Alternating heat and cold and alternating drying and wetting may, like the process of weathering of rocks, cause minute cracks in a hard outer coat. A slight change of hydrogen-ion concentration may affect the composition of both wall and reserves, rendering for example the hydrophilic colloids more ready to imbibe water. And what can 'time' do? May it not be that in the slow metabolism of the living protoplast, enough carbon dioxide has accumulated to

change the hydrogen-ion concentration so that the colloidal state of reserves and wall is changed from within and the wall is made permeable to water and oxygen? Indeed, there comes a time when prompt germination must be the response to right conditions of air and water and temperature, and if these are not forthcoming the spore at last dies: its wall permeable and its reserves exhausted. There is, presumably, a limit to the viability of spores, although some may live for years, and it is a source of everlasting wonder how a microscopic spore can remain viable so long. Constant change must be taking place, else it would not be alive. But what incredibly slow metabolism this is.

At the risk of 'stating the obvious' once again I would remind you of the oft-demonstrated fact that for successful germination spores, as well as seeds, require water and air at a suitable temperature. A spore that has matured and completed its dormancy in water responds to aeration; an air-borne spore, ripe for germination, responds to moisture. These are the well-known 'conditions of germination', and remain the conditions of germination after the application of any of these various 'agents' that have been shown effective in *initiating* germination. But how low the oxygen supply may be I realized when germinating the resting sporangia of *Blastocladia Pringsheimii* in stale water under a coverslip sealed with wax to the slide (Blackwell, 1940), and how low the water supply may be has recently been pointed out by Brodie and Neufeld (1942) on germinating the conidia of *Erysiphe polygoni* at a humidity approaching zero.

The oospores of species of *Phytophthora* are peculiarly resistant to germination. de Bary (1881) reported germination of oospores of *P. omnivora* in 1866 and again in 1879. He kept the oospores for months in water and waited patiently for germlings, and he made the observation that oospores collected in June germinated more readily in the spring of the following year after a cold December. In 1914 Pethybridge found occasional germinating oospores of *P. erythroseptica* in cultures nine months old, and published satisfactory drawings by Lafferty of two of these. Lafferty and Pethybridge reported germination of oospores of *P. Syringae* in 1922. Rosenbaum (1915, 1917) made a serious attempt to germinate oospores of *P. Cactorum*, and after many failures in 1912 and 1913 with oospores of all ages, he tried burying the oospores out of doors over the winter of 1913–14, so that they should be, as he said, 'under as natural conditions as possible'. In 1917 he claimed that 'to date *Phytophthora Cactorum*... and *Phytophthora Fagi*... have been germinated... after a period of rest and under proper conditions'. Since that time to the present day there have been some half-dozen records of the finding of germinating oospores, usually in old cultures of these and other species of *Phytophthora*, but as Tucker (1931) writes in his monograph of *Phytophthora*: 'Definite observations on germinating oospores are few.'

Dormant oospores of this strain of *P. Cactorum* are colourless and transparent and perfectly spherical and lie loosely within the colourless oogonial wall, for at the height of their dormant state they have their minimum volume. The homogeneous protoplasm is enclosed within the double wall:

a thin transparent outer oospore wall and a thick transparent inner oospore wall. Within the protoplast are two striking objects: an excentric refringent globule which turns brown in osmic acid and is probably of highly saturated fat, and a small and yet more highly refringent body which turns black in osmic acid. It contains the nucleus and perhaps a plastid. One learns not to expect immediate germination in such a hard, shining oospore. In cultures which are several months old there may still be found oospores like this. There are others in which the protoplasm can no longer be discerned and the whole spore appears 'glassy'. These are dead. And yet again there are others which look active and vigorous, which are larger (almost filling the oogonial cavity), thin walled, the protoplasm more abundant and with the appearance of a uniform emulsion in which lie several refringent globules among which the nucleus is not readily distinguished. These are preparing for germination.

There is no doubt that the precise conditions that ensure germination of the oospore lie within narrow limits. A drop of water is all that is required to germinate an oospore which has been formed under proper conditions, which has been stored in a slowly drying medium, which has been allowed to lie dormant for the right length of time (which time is partly determined by the temperature at which the oospore has been kept), and finally whose three protective envelopes have been at last rendered permeable by various physical and chemical means. It is not to be wondered at that the drop of water does not cause immediate germination of all the oospores it moistens in a culture of fully matured and after-ripened oospores, which are enlarged until they fill the oogonial cavity and press against the oogonial wall, whose reserves are already assimilated into the cytoplasm, whose nuclei have undergone three or four divisions, whose walls are thin; oospores which, in fact, appear to be just on the point of germination. In such a culture of oospores as a rule only a few at a time will be found germinating.

Many unsuccessful attempts were made, in the early years of this study, to germinate in quantity the oospores of *P. Cactorum*. At first the experiments were of a desultory nature: of the 'hit or miss' variety, anything and everything previously found effective in spore germination being tried in the hope that by chance a successful method might be found. And in the end it was by chance that a way was found. It was in December 1924 that a few oospores were seen to be germinating *in situ* in two nine-month-old cultures on slopes of potato-mush agar which had been inoculated in the previous March and were still moist, a condition due in part to the large size of the test-tube in use and the considerable depth of agar. It is just possible that a drop of water of condensation may have initiated the germination (the culture had been kept on the laboratory bench subject to the fluctuating temperature of day and night) but fresh water it seems is not necessary: the moist, stale medium is enough. One of these nine-month-old cultures contained bacteria and percentage germination was, if anything, higher in this tube. In nature, bacteria must abound in the rotting tissues of the host and in the soil where the oospores presumably germinate in due course. Experiments were made later with cultures

which had been especially inoculated with bacteria and these were found to compare favourably with pure cultures in the quantity of germinating oospores.

At this stage of the investigation then, the special conditions that seemed necessary for germination of these oospores were: (*a*) a certain minimum age for full maturation of the oospore (it appeared to be nine months); (*b*) a slowly drying medium, never quite dry. It seemed too that bacteria were helpful in some way.

In February 1929 a culture only four months old (inoculated 18 October 1928) was examined and found to be full of oospores in a particularly vigorous state, apparently on the point of germination. To a portion of this culture, water was added (6 February 1929), and on the following day a few oospores were found with germ-tubes. Clearly neither a great age nor the presence of bacteria (for this culture was clean) were necessary factors in germination. Inquiry showed that on 15 January the culture had been taken from an incubator (20° C.) and sent by hand, exposed on the journey to a temperature little above freezing-point, and afterwards kept on the laboratory bench (15° C.). It seemed that chilling of the oospores might be a means of obtaining germination. Acting on this hypothesis some preliminary experiments were made with chilling. Some cultures were kept out of doors on a flat roof leading from the laboratory, and controls were kept both on the laboratory bench at about 60° F. (= 15° C.) and in the incubator at 23° C. The results of this trial were encouraging enough to proceed with definite experiments on refrigeration as a means of encouraging germination, and these began in 1932.

Cultures were made in groups of three (A, B and C) in flasks or tubes, with a fair depth of agar; and they were inoculated at any time of year but usually in March, July and November. All three cultures of any one group were kept for the first month on the laboratory bench (15° C. approx.). Then culture A was put out on the roof shaded from direct sunlight and exposed to a wide range of day and night temperature. A maximum and minimum thermometer hanging beside the culture recorded the extremes of temperature. Culture B was stored in the refrigerator room attached to the college kitchen where the temperature varies around 35° F.: it may fall to freezing-point, or rise to 45° F. and over, when much in use and the door frequently opened. Culture C was kept, as a control, on the laboratory bench. But it was an unsteady control for two reasons: (*a*) the laboratory temperature, 60° F. during the day, dropped at night and on Sundays, when the heat was turned off, to 45° F.; (*b*) cultures kept in the laboratory dried up sooner or later and the oospores died of drought. The cultures A, B and C were frequently tested for germination and compared. A fresh piece of mycelium with oospores was taken each time and soaked in water, the main body of the culture being returned immediately to the special conditions under which it was kept.

After three years of experimenting thus, it was quite clear that refrigeration could be used as a practical method of encouraging germination. The C cultures that remained moist long enough gave germination after eight or nine months, but rarely in any quantity. The A cultures gave

erratic results, usually poor, but sometimes in winter very good, and then it was found that low temperatures had been recorded out of doors. Observations on the A cultures were complicated by the heavy production of chlamydospores on hyphae which grew during spells of milder weather. The B cultures did not develop conidia or chlamydospores, or indeed grow much at all; but their oospores steadily and quickly ripened at a temperature just above freezing-point and, when three months old, gave ready germination.

In 1939 a fresh impetus was given to the work when Miss Waterhouse joined me and with meticulous care repeated these experiments and explored further. Two lines of inquiry were followed. Firstly, was there any other set of conditions, or any other substance, which would either successfully replace chilling as a means of obtaining abundant germination of oospores, or intensify the results so far obtained, and how far were other agents limiting factors? Secondly, could germination of oospores younger than three months be obtained by chilling and subsequent soaking in tap water, and if so what proportion of time should be allowed (*a*) for ripening of the oospores, (*b*) for chilling, (*c*) for soaking in water? The following trials were made with unchilled oospores to see if other means could be found of breaking dormancy; and again with chilled oospores to see if the effects of chilling could be intensified.

Enzyme extracts were used to try to digest away the impermeable walls or at least to render them more permeable. Potato-skin extracts were made for the sake of the tyrosinase known to be present, because tyrosine had, from microchemical tests, been suspected in the inner oospore wall. Different strengths were tried for different lengths of time. The effect was to raise the percentage germination of chilled oospores, but germination was rarely abundant and then not more than 50 %. Spores which germinated in the extract soon had their germ tubes digested away if not removed to distilled water.

Yeast, known to contain a variety of enzymes and growth-promoting substances, was tried. The effect of the yeast extract, however, was to retard germination. The cultures treated showed vigorous hyphal growth, with sporangia, from the old mycelium. It appeared that the growth-promoting substance was affecting the mycelium but not its oospores.

The proprietary horticultural product Hortomone A was tried, and the effect was strikingly parallel to the action of the yeast extract. It is possible that growth-promoting substances cannot penetrate the outer oospore wall.

McKay (1937, 1939) had obtained a high percentage of germination with oospores of *Peronospora Schleideniana*, using potassium permanganate. His method was followed, but the oospores treated gave about the same percentage germination as the controls.

Since volatile substances, including carbon dioxide, have been found effective in spore germination, and as this suggested the production of acid conditions which might affect the spore walls, weak acids were tried. (This had at least the secondary value of destroying other parts of the fungus, viz. hyphae and less protected spores, and so rendering observation

on the resistant spores less obscure.) Spores dipped in 3 % sulphuric acid for less than a second are not killed but germination is inhibited or retarded.

And as it seemed that the helpful effect of bacteria might possibly be to render the medium alkaline (Berridge, 1924) weak alkalis, ammonia (*p*H 8·2), lime water (*p*H 8·0–10·0), baryta water (*p*H 8·0–10·0) and alkaline tap water (*p*H 7·6–8·0) were tried, both alone and alternately with weak acids. Considering the colloidal nature of the oospore wall, it seemed likely that slight changes of hydrogen-ion concentration might affect the water absorption of the hydrophilic colloids, especially changes from slightly acid to slightly alkaline conditions. In all the alkaline media percentage germination was higher than in distilled water (which was slightly acid *p*H 6·6). Lime water gave good results but no better than tap water. The tap water in use was, however, found to be slightly alkaline (*p*H 7·6–8·0) and to have a comparatively high calcium content (estimated at 19 parts in 100,000). It was then suspected that increased germination was due not so much to the presence of hydroxyl ions as to certain other ions, notably calcium. Further experiments on alkalis were therefore worked in conjunction with those concerned with the calcium content in relation to the hydrogen-ion concentration.

The outcome of these and other experiments made by Miss Waterhouse was to confirm the previous finding that the usual procedure of chilling the oospores and then soaking them in refreshed tap water cannot be bettered (provided the tap water has approximately *p*H 7·6–8·0 and Ca 15–19).

Miss Waterhouse then proceeded to experiment with the time factor, and by orderly and precise means she shortened the requisite time to two months, with a minimum of one week's refrigeration when the oospores are about a month old.

Change of condition may be an important factor in the actual germination (i.e. exit of germ tube): e.g. (*a*) alternate drying and wetting, causing cracking, (*b*) alternate heating and chilling, causing cracking (and this change may be between almost zero and laboratory temperature or between laboratory temperature and hot water), (*c*) alternate alkalinity and acidity, changing the colloidal state (and this may explain the observed fact that water refreshed at intervals is better than either continuous standing water or running water).

No exact specifications can be made about the age of spore that can most usefully be treated, the ideal period of treatment or the time required for soaking in water before the germ tube is put out; but it is possible to a certain extent to give instructions for successful germination of the oospores of *P. Cactorum*, thus: given well-formed and normal oospores (1) allow full maturation (at least one month) at 10–15° C. under moist conditions (neither wet nor completely dry); (2) allow a further period of dormancy under similar conditions (one to eight months); (3) refrigerate at a temperature just above freezing-point for a week or two; (4) soak in water (the following have been proved satisfactory: tap water of *p*H 8·0 and Ca content 19; soil solution of *p*H 7·0 and Ca content 15); (5) change the

solution daily or at least at frequent intervals; (6) wait for one to three (or more) weeks for germination.

When interpreting the results of germination it must be remembered that each oospore is an individual unit. It has been specially formed with its own nuclear fusion, its own thickness of wall, its own amount of reserves; it has its own size, its own age. There is no 'mass production' of oospores. And so all will not germinate at once. There may be one or two on the first day, and more on succeeding days until all viable ones have germinated. The non-viable ones may be immature, or they may be dead, having been stored under too hot or too dry conditions (dead oospores are easily recognized by a hard glassy look which is unmistakable), or they may have entered upon a state of 'secondary dormancy'. This condition is not understood, but it is a deeper dormancy than the first. The oospore looks just primed for germination, but the magic touch is rare and elusive that will break down the last barrier. This seems to lie in the relation of the outer oospore wall to the activity of the protoplast within.

As one would expect, these oospores are stored under perfect conditions in nature when they are in the ground over winter, and the warmth and rain in spring gives perfect conditions for germination. But that the oospores are as variable and as resistant in nature as in the laboratory is probable, and herein lies the success of the parasite. No set of conditions, however favourable they appear to us to be, are optimum conditions for all these spores. There is enough variety in the size and age of the spore, in the nature and thickness of the different walls, and in the nature and amount of the reserves, quite apart from difference of treatment, to prevent wholesale germination.

But the question still remains: what exactly is the dormancy of these oospores of *P. Cactorum* and how can refrigeration affect it? To attempt to answer this question it is necessary to know the composition of the enveloping wall layers and the nature of the reserves. Two sources of information are: (1) their microchemical reactions at different stages of development, and (2) the history of their development.

From unpublished work done by Miss Waterhouse on the microchemistry of the substances of the spores, I may pass on, with her kind permission, this information:

The oogonial wall has traces of fatty acids and at least three other constituents:

(*a*) A substance which is removed by treatment with chlorine water and sodium sulphite. This may be a hemicellulose.

(*b*) Cellulose which gives characteristic reactions after the hemicellulose has been removed and which can be dissolved away by cuprammonia.

(*c*) Something which remains as a resistant framework after both (*a*) and (*b*) have been removed.

There is reason to believe that the oogonial wall is not impermeable to water, but owing to its inelasticity it may offer mechanical resistance to the swelling of the spore within.

The outer oospore wall is characteristically inert: it gives few reactions:

(*a*) Insolubility after prolonged treatment with 72 % sulphuric acid.

(*b*) A great extensibility when treated with concentrated sulphuric acid, and other strong acids.

(*c*) A yellow or brown colour with iodine reagents.

(*d*) A red colour with ruthenium red.

This wall and the protoplasm are all that remain after treatment with 72 % sulphuric acid, revealing the protoplasmic origin of the outer oospore wall direct from the oosphere membrane and the periplasm. It is of complex protein and pectic material and is the most resistant and most impermeable layer.

The inner oospore wall gives reactions which suggest that the wall is of a triple nature having a basis of cellulose impregnated with some hemicellulose and a tyrosine compound. Later a substance appears that gives a bright blue colour with lacmoid. This may be callose though it does not give all reactions for callose. Whereas the outer oospore wall is highly *extensible*, the inner oospore *swells* enormously in sulphuric acid. This is a layer mainly of reserve food material.

The other source of information as to the nature of these wall layers and the reserves is a close observation of their formation during maturation of the oospore and their fate on germination.

The oogonial wall originates from the hyphal wall. After the oogonia and antheridia are cut off by septa from the hyphae which have borne them, their walls undergo some change, and not exactly the same change in each as is readily shown by the different colour they give with chlor-zinc-iodine. They are both extraordinarily resistant to bacterial action and to strong chemicals. On germination of the oospore the antheridium is as a rule still attached to the oogonium and the oogonial wall has to be forcibly cracked by the swelling oospore. This is so difficult sometimes that a germ tube may be seen winding about within the oogonial wall unable to make a way out. The firm and persistent nature of this wall must often inhibit germination.

The outer oospore wall begins as a plasma membrane, i.e. it is protoplasmic in origin. It is formed at a very early stage, beginning as the oosphere membrane before fertilization. After fertilization it becomes rapidly firmer and upon it is deposited the thin nucleated periplasm whose degenerating nuclei stain readily at this stage with nuclear dyes. It becomes impermeable and is undoubtedly the layer most difficult of penetration by water and gases, and the seat of greatest resistance to germination. It is finally extended by pressure of the swelling protoplast within but restricted by the oogonial wall without.

The inner oospore wall is deposited from within upon the outer oospore wall. It is formed very rapidly within a day after fertilization, and long before nuclear fusion. But it is not absorbed as rapidly as it is formed, and on preparation for germination its compound nature can be seen. While it is being slowly digested by the protoplast it has an eroded appearance: radiating lanes can be seen in it, which suggest that along certain radii are the more easily digested substances. This process is dependent on internal

activity of the protoplast and independent of entry of water. Quite often the germ tube grows out before this layer is completely absorbed, and this half-digested inner oospore wall may be left behind in the otherwise emptied oospore. This depends apparently on how soon the outer oospore wall permits water to enter.

It appears then that dormancy in these oospores may be attributed to several causes, and here are some of them:

(1) *Incomplete maturation.* The antheridial and oosphere nuclei do not fuse at once on entry of the former into the latter. The delay may be as long as a month, and although the inner oospore wall and the fat globule appear to be fully developed, the spore is not ripe until nuclear fusion has taken place.

(2) *Incomplete dormancy.* No germination has been obtained under two months. Digestion of the deposit of cellulose and protein which we call the inner oospore wall, and desaturation and assimilation of the oil globule do not begin until after nuclear fusion and take at least a month. In fact these reserves are often not completely assimilated if germination takes place so soon.

(3) *Mechanical resistance of the oogonial wall.*

(4) *Impermeability of the outer oospore wall.*

These causes of dormancy are strongly reminiscent of dormancy in seeds, and earlier this year the Fellows of the Linnean Society discussed 'Time, temperature and humidity in the germination of seeds'. Although one is a multicellular organ and the other usually not more than a single cell, seeds and spores have much in common (I am again stating the obvious). They each have an impermeable envelope: the seed has a cuticle, the spore has an epispore. Each may have a weak spot in this envelope; in the seed it may be the micropyle or the hilum, in the spore the point of entry of the fertilization tube or the point of abstriction. Their constitution is alike in that they both have substances in wall and reserves in a colloidal state, on which hydrophilic colloids depends in part the intake of water. Investigators of both seeds and spores have pointed out that the germination is in part controlled by the conditions under which development took place and by conditions of storage. Both seeds and spores may pass into a state of secondary dormancy, if preparation for germination has begun and been interrupted.

The use of chilling as a means of breaking dormancy is well known for seeds as well as spores. From the Boyce Thompson Institute (Barton, 1939) has recently come a recommendation for the after-ripening of certain seeds, viz. storage in moist condition at a temperature of 33–49° F. for two, three or more months. What can be happening at these low temperatures? We are told that in the freezing of a gel the configuration of colloidal systems is altered, because, on freezing, a gel ice separates, leaving relatively dehydrated gel and, on thawing, all the water is not at once or indeed readily reabsorbed. And again we are told of the metabolism of fats and oils and of the production of auxins at low temperatures. Chilling, then, may act mechanically in producing minute cracks in the impermeable

wall layers, or chemically by encouraging reactions that proceed best at a temperature just above freezing point.

I have said enough to indicate the high complexity of this spore and the difficulty of defining the exact conditions of its germination. We are concerned here with elaborate chemical substances: proteins, pectins, hemicellulose, cellulose and fats and these in colloidal state. The problem must be passed on to the biochemist and biophysicist and the student of cell-wall structure who some day may enable us to answer the questions that as yet remain unanswered: What are the precise conditions under which water is at last permitted to enter the spore and the germ tube to grow out? and how does chilling help?

Meanwhile the oospores continue to germinate one at a time and never all together, but with some remaining over for another time.

REFERENCES

BARTON, L. V. (1939). Experiments at Boyce Thompson Institute on germination and dormancy in seeds. *Sci. Hort.* (*H.E.A.*), VII, 186–93.

DE BARY, A. (1881). Zur Kenntniss der Peronosporeen. *Bot. Ztg Jahr.* XXXIX, 521–625.

BERRIDGE, E. M. (1924). The influence of hydrogen-ion concentration on the growth of certain bacterial plant parasites and saprophytes. *Ann. appl. Biol.* XI, 73–85.

BLACKWELL, E. M. (1940). The life cycle of *Blastocladia Pringsheimii* Reinsch. *Trans. Brit. myc. Soc.* XXIV, 68–86.

BLACKWELL, E. M. (1943). The life history of *Phytophthora Cactorum*. *Trans. Brit. myc. Soc.* XXVI, 71–89.

BRODIE, H. J. & NEUFELD, C. C. (1942). The development and structure of the conidia of *Erysiphe polygoni* DC. and their germination at low humidity. *Canad. J. Res.* XIX, 41–61.

LAFFERTY, H. A. & PETHYBRIDGE, G. H. (1922). On a *Phytophthora* parasitic on apples which has both amphigynous and paragynous antheridia; and on allied species which show the same phenomenon. *Sci. Proc. Roy. Dubl. Soc.* XVII (N.S.), No. 4, 29–43.

MCKAY, R. (1937). Germination of oospores of onion mildew, *Peronospora Schleideniana*. *Nature*, CXXXIX, 758.

MCKAY, R. (1939). Observations on onion mildew caused by the fungus *Peronospora Schleideniana*. *J. Roy. hort. Soc.* LXIV, 272–85.

PETHYBRIDGE, G. H. (1914). Further observations on *Phytophthora erythroseptica* Pethyb., and on the disease produced by it in the potato plant. *Sci. Proc. Roy. Dubl. Soc.* XIV (N.S.), No. 10, 179–98.

ROSENBAUM, J. (1915). *Phytophthora* disease of Ginseng. *Bull. N.Y. Cornell Univ. agric. Exp. Sta.* no. 363.

ROSENBAUM, J. (1917). Studies of the genus *Phytophthora*. *J. agric. Res.* VIII, 233–76.

TUCKER, C. M. (1931). Taxonomy of the genus *Phytophthora* de Bary. *Res. Bull. Missouri agric. Exp. Sta.* no. 153, 208 pages.

Note

Pending the publication of the papers cited below, (1) tables of the results of experiments in germination of the oospores and (2) tables of microchemical reactions, together with coloured diagrams of these, are available for reference at Royal Holloway College and may be consulted there.

BLACKWELL, E. M. & WATERHOUSE, G. M. Refrigeration as a means of eliminating dormancy in oospores of *Phytophthora Cactorum*.

WATERHOUSE, G. M. The microchemistry of wall and reserves of hyphae and spores of *Phytophthora Cactorum*.

For illustrations to this address, see: BLACKWELL, E. (1943). The life history of *Phytophthora Cactorum* (Leb. & Cohn) Schroet. *Trans. Brit. myc. Soc.* XXVI, 71–89.

(*Accepted for publication* 19 *December* 1942)

FURTHER OBSERVATIONS ON AQUATIC HYPHOMYCETES OF DECAYING LEAVES

By C. T. INGOLD, *Department of Botany, University College, Leicester*

(With Plates V and VI and 6 Text-figures)

Introduction

Recently an account was given (Ingold, 1942) of a flora of aquatic Hyphomycetes on submerged decaying leaves of alder from a stream in Leicestershire. This stream, which drains Cropston Reservoir, flows between fields and its banks are lined mainly by alders with occasional willows, and leaves of these trees make up the main mass of organic debris in the stream-bed.

From January to April 1942 samples of oak leaves were examined from the tiny streams which flow through Swithland Wood. These streams are from one mile to a mile and a half from the Cropston stream and are not connected with it, but, like it, they finally reach Swithland Reservoir. In spring, the beds of the streams in Swithland Wood are lined with decaying oak leaves. When samples of these were brought into the laboratory and kept at 15–18° C. for a day in large dishes of shallow water, rich crops of aquatic Hyphomycetes developed. Of the sixteen species already reported on alder leaves, the following thirteen occurred on the oak leaves, most of them in abundance and with great regularity, especially if the leaves had decayed almost to leaf-skeletons: *Tetracladium Marchalianum* De Wild., *Clavariopsis aquatica* De Wild., *Lemonniera aquatica* De Wild., *Varicosporium Elodeae* Kegel., *Tetrachaetum elegans* Ingold, *Alatospora acuminata* Ingold, *Articulospora tetracladia* Ingold, *Heliscus longibrachiatus* Ingold, *H. aquaticus* Ingold, *Anguillospora longissima* (Sacc. & Syd.) Ingold, *Tricladium splendens* Ingold, *T. angulatum* Ingold and *Flagellospora curvula* Ingold.

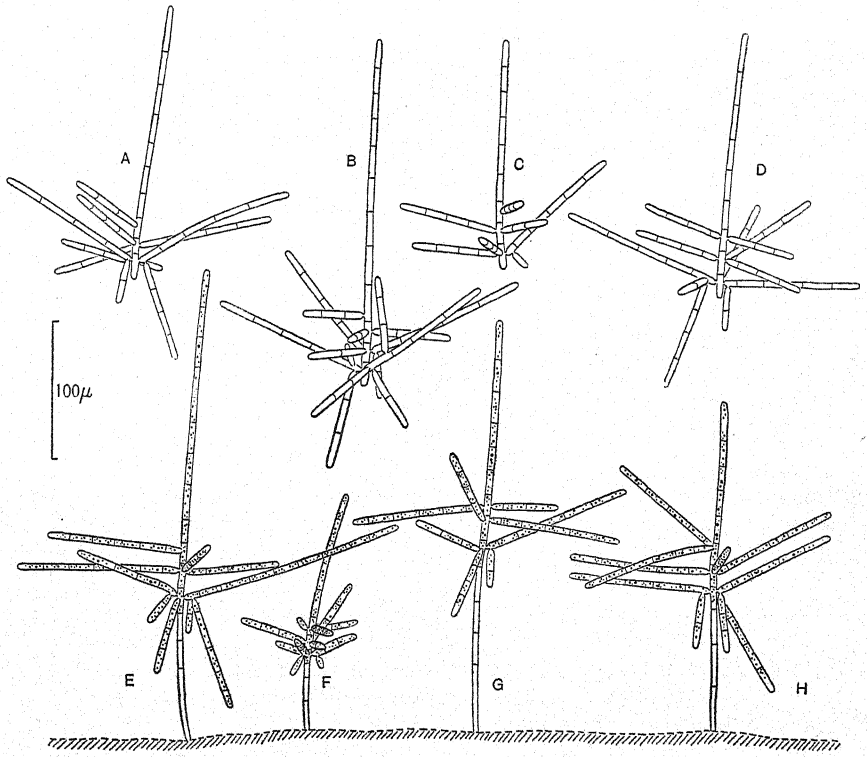
With these thirteen species two other submerged aquatic Hyphomycetes were common on the oak leaves. From the end of January to the middle of April some ten collections of decaying oak leaves were made, at roughly weekly intervals, from Swithland Wood, each of from ten to twenty leaves either in the leaf-skeleton condition or approaching that state. The two new fungi described below were found on some leaves of every collection.

Dendrospora erecta n.gen., n.sp.

The branched septate vegetative hyphae of this fungus ramify within the veins of the decaying oak leaves, and the conidiophores project at right angles into the water (Text-fig. 1 and Pl. V). In most aquatic Hyphomycetes miniature forests of conidiophores grow out from the decaying oak leaves, and hundreds, or even thousands, may be seen on a single leaf, but in *Dendrospora* the conidiophores may occur singly or, more usually, in

groups of rarely more than a dozen. This species seems to produce a few large spores rather than many smaller ones. I have rarely seen more than twenty or thirty conidiophores on a single leaf.

The conidiophore is straight, 50–120 μ long, 4 μ broad and 2–4-septate. A single branched, septate conidium of the aleuriospore type is formed terminally. The conidium (Text-fig. 1 and Pl. V, figs. 4, 6 and 7) consists of a long main axis with lateral branches, some of which branch again.



Text-fig. 1. *Dendrospora erecta* n.gen., n.sp. A–D, spores; no cell-contents are shown. E–H, conidiophores; the dots represent the oil-drops in the cells of the spore, but no other cell-contents are shown. In F the spore is still young and neither the main axis nor the branches have nearly reached their final length. The tissue of the oak leaf is indicated diagrammatically.

All the text-figures in this paper were drawn with the aid of a camera lucida, from living specimens.

The main axis of the spore is straight, of uniform width, and continuous with the conidiophore. It is 150–300 μ long, 4–5 μ broad, 8–12-septate with each cell containing a number of small oil-drops. From the lower region of this main axis, but rarely more than 50 μ from its base, branches arise usually in pairs or in whorls of three, the number of such whorls or pairs varying from two to four. These primary laterals grow out at right angles to the main axis. They are 2–8-septate, 50–180 μ long, 4–5 μ broad and each is abruptly constricted to about 2 μ where it joins the axis. The

lowermost of these branches may branch again to give secondary laterals which always arise near the bases of the primary ones. These secondary laterals are 10–90μ long, 4–5μ broad and, like the primary ones, are constricted to 2μ at their bases.

Since the conidiophore passes without change of width or direction into the main axis of the spore, it is not clear, at first sight, where the conidiophore ends and the conidium begins. The actual junction is at the cross-wall immediately below the insertion of the lowermost branches of the spore. This was indicated by an examination of liberated spores and by watching specimens in hanging-drop cultures when disjunction at this cross-wall was observed. Thus the specimen shown in Pl. V, fig. 2, was kept under observation for a number of hours and the spore was seen to separate at the point shown by the arrow. One feature distinguishes the cells of the spore from those of the conidiophore; all the cells of the spore contain several small oil-drops, but in the cells of the conidiophore these are absent or poorly developed.

The degree of branching of the spore varies considerably, the number of primary laterals being six to twelve and secondary laterals one to five. The largest spores are remarkably big, being more than a third of a millimetre long and quite bushy, they can be seen with a hand lens of low power.

In water the spores germinate very slowly or not at all, but they germinate readily in 2 % malt solution, or on malt agar, by means of rather narrow germ tubes which develop from the ends of the main axis and from the tips of the branches.

On malt agar a branched, septate, hyaline mycelium is produced, but, although I have grown this organism in unifungal culture, I failed to secure colonies free from bacteria.

This fungus is especially interesting when compared with the aquatic Hyphomycetes previously described (Ingold, 1942), because the branched spore appears to reach the highest development yet observed. When compared with the other aquatic Hyphomycetes with branched spores, it seems to bear the greatest resemblance to *Tricladium splendens*. In both fungi the conidium is a terminal aleuriospore produced singly at the end of a conidiophore normally unbranched. In both the main axis of the spore is continuous with the conidiophore and laterals are produced which are constricted abruptly at their junction with the axis. However, in *T. splendens* there are only two lateral branches and these, in contrast to the six to twelve of the present species, do not give rise to secondary branches.

In spite of the resemblances it seems clear that this fungus cannot be placed in the genus *Tricladium*, and because of the tree-like form of the spore the generic name *Dendrospora* is proposed.

Dendrospora n.gen.

Submerged aquatic fungi with branched, septate mycelium. Conidia (aleuriospores) terminal, septate, branched, each consisting of one main axis with several secondary and tertiary ramuli.

Dendrospora gen.nov.

Fungi aquatici submersi mycelio repente, septato, ramoso. Conidia (aleuriosporae) acrogena, septata, ramosa, ex uno ramo principali et ramulis secundariis et tertiariis compluribus constantia.

Dendrospora erecta n.sp.

Submerged aquatic fungus with branched, septate, hyaline mycelium. Conidiophores simple, 50–120 μ long, 4 μ broad, 2–4-septate. Conidia (aleuriospores) apical, hyaline, septate, branched; main axis 150–300 μ long, 4–5 μ broad, continuous with the conidiophore; secondary ramuli 6–12, 50–180 μ long, 4–5 μ broad, constricted at the base to 2 μ, arising (usually in pairs or in whorls of three) from the lower part of the main axis; tertiary ramuli, which may arise from the lowermost secondary ramuli, 10–90 μ long, 4–5 μ broad, constricted at the base to 2 μ.

On submerged decaying leaves of *Quercus* sp. from streams in Leicestershire, England.

Dendrospora erecta sp.nov.

Fungus aquaticus submersus, mycelio repente, hyalino, septato, ramoso. Conidiophora simplicia, 50–120 μ longa, 4 μ lata, 2–4 septata. Conidia (aleuriosporae) acrogena, hyalina, septata, ramosa; ramus principalis 150–300 μ longus, 4–5 μ latus, cum conidiophoro continuus; ramuli secundarii 6–12, 50–180 μ longi, 4–5 μ lati, basi ad 2 μ constricti, plerumque bini vel verticillato terni, ex inferiore parte rami principalis orientes; ramuli tertiarii ex infimis ramulis secundariis aliquando exorientes, 10–90 μ longi, 4–5 μ lati, basi ad 2 μ constricti.

Hab.: in foliis putrescentibus *Quercus* sp. in fluminibus jacentibus Leicestershire, Anglia.

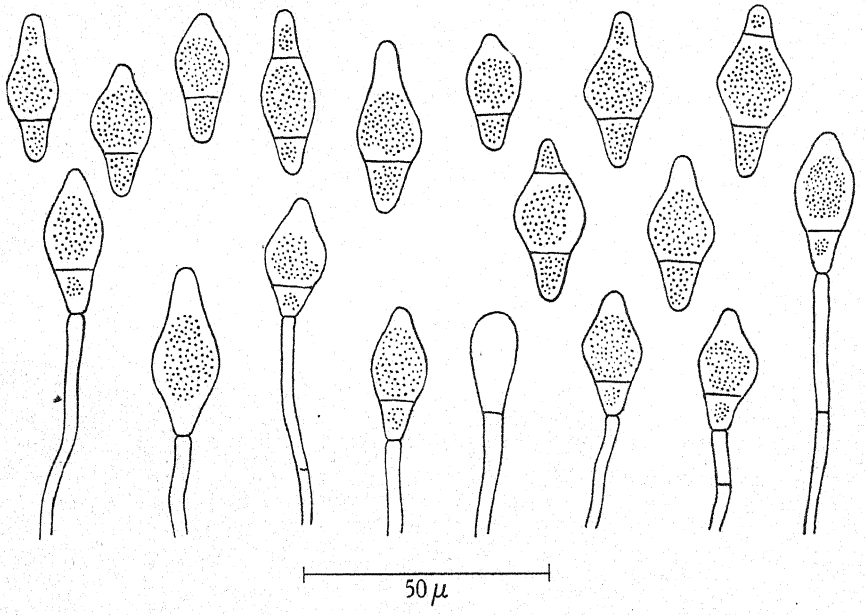
Piricularia aquatica n.sp.

This fungus (Text-figs. 2–5 and Pl. VI, figs. 1–6) was common on submerged decaying leaf-skeletons of oak in the streams of Swithland Wood in Leicestershire from January to April 1942. It was also seen on similar leaves collected in April from a stream near Westerham, Kent, and once on a submerged decaying leaf of hawthorn from the stream which drains Cropston Reservoir in Leicestershire.

The mycelium of the fungus appears to be within the veins of the leaf with the conidiophores projecting at right angles into the water. The conidiophore is usually 20–60 μ long, 2–3 μ broad and bears a single terminal conidium of the aleuriospore type. The conidia, formed below water in nature, are somewhat lemon-shaped, 24–34 μ long, 12–16 μ broad, hyaline and usually two-celled with the upper cell much larger than the lower. The conidia are often three-celled and then the middle cell is large with a small one above and below it. Occasionally the spores are unicellular. The conidia have a pearly appearance due to an abundant supply of glycogen.

The fungus was isolated in single-spore pure culture on malt agar. On this medium a very compact colony of branched septate hyphae was formed.

The hyphae were colourless at first, but soon became grey with a slight greenish tinge. The mycelium was mainly on the surface of the agar or slightly submerged, although there was also a very sparse growth of greyish green aerial hyphae reaching a height of seldom more than 1 mm. Many of these hyphae had terminal or intercalary hyphal coils. The general colour of the colony was greenish grey, but the central zone was greyish yellow, due to a brilliant orange-yellow pigment, produced in the medium by the older parts of the mycelium, in combination with the grey of the hyphae. In a colony thirty-two days old, grown on malt agar at 16–18° C. and having a diameter of 6·6 cm., the central zone (3·5 cm. in diameter)



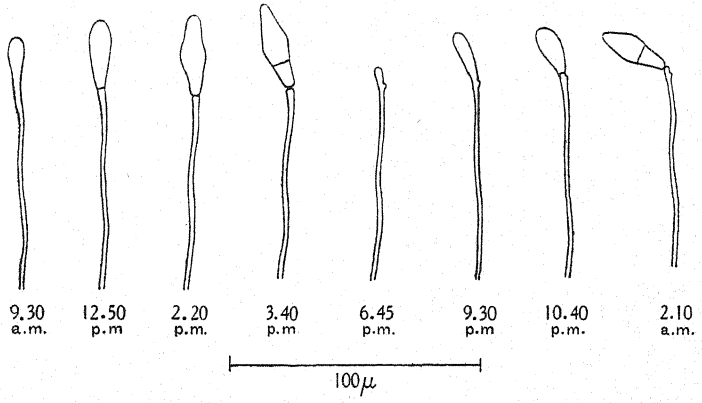
Text-fig. 2. *Piricularia aquatica* n.sp. Spores and conidiophores. The only contents shown are the glycogen vacuoles which are indicated by stippling. In one spore attached to a conidiophore (fifth from the left) development has not proceeded far and no glycogen has yet accumulated. From decaying oak leaves.

was dominated by the yellow pigment; outside this was another zone (1·4 cm. wide) of pale greenish grey, and finally a very narrow zone (0·15 cm. wide) of uncoloured hyphae forming a white fringe. Cultures grown in the dark showed no zonation, but those grown in ordinary light were sharply zoned by concentric rings of daily growth.

Using spores from the decaying leaves, a large number of single-spore cultures were made. For the first week or so none of these produced any aerial spores, but when a strip of a colony was immersed in water very abundant conidia were produced on submerged conidiophores within twenty-four hours. These agreed with the submerged aquatic conidiophores observed in nature, but the spores tended to be rather longer and narrower

(Pl. VI, figs. 1, 2). At the moment of liberation these spores were usually 1-septate, but there was a strong tendency for an additional septum to form, delimiting a small apical cell, before germination occurred. Like those found on the leaves, the spores were hyaline and contained abundant glycogen.

Development of the spores was watched in hanging-drop pure cultures and the course of this is shown in Text-fig. 3. The first spore to be produced is truly terminal and, when ripe, it separates from the conidiophore. Then, just to one side of the cross-wall which originally separated the conidiophore from the first spore, a protuberance is produced from the end of the conidiophore which is soon cut off as the primordium of the second spore. This type of successive conidium (aleuriospore) development from the apex of the conidiophore is reminiscent of *Trichothecium roseum* and is also similar to what occurs (Ingold, 1942) in *Articulospora tetracladia* and *Tricladium angulatum*.



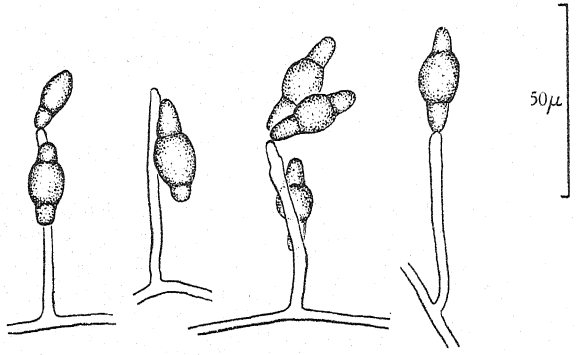
Text-fig. 3. *Piricularia aquatica*. Spore development as seen in hanging-drop pure culture. The first spore, arising in a truly terminal position, was liberated about 4 p.m.; the succeeding spore about ten hours later.

When first isolated some of the single-spore cultures, after ten days or so, produced aerial conidia rather sparingly on short conidiophores (Text-fig. 4) which arose as lateral branches of certain aerial hyphae. The aerial conidia are clearly homologous with the submerged aquatic conidia, but there are certain striking differences. First, the aerial conidia (Text-fig. 5) are mostly greenish brown, due to pigmentation of the cell walls, although they are sometimes hyaline. Secondly, they are normally three-celled with the middle cell much the biggest, whilst the submerged aquatic spores tend to be two-celled. Thirdly, in the cells of the spore are numerous oil-drops in contrast to the glycogen of the aquatic spores.

Although at first aerial conidia were produced sparingly on certain of the single-spore cultures, others failed to form such spores. Further, after two months in culture on malt agar, subculturing on to the same medium invariably gave colonies which, although they grew with apparently undiminished vigour, failed to form aerial spores.

The aquatic spore germinates readily in 2 % malt solution or on malt agar by a germ tube produced from each pole of the spore.

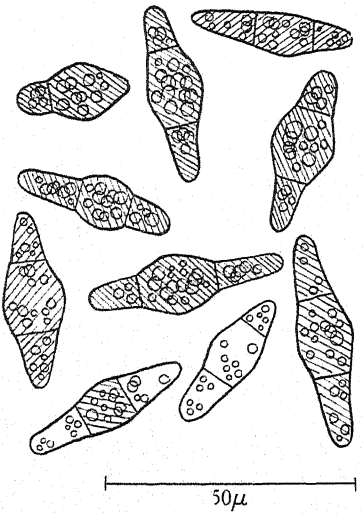
The classification of this fungus is difficult, especially in view of the differences in the aleuriospores produced below water in nature and aerially



Text-fig. 4. *Piricularia aquatica.* Undisturbed aerial conidiophores growing in pure culture on malt agar. The shading on the spores is to show their form; it does not represent their contents. Under the conditions of illumination used, the interior of the spores and hyphae could not be distinguished and cross-walls, which may have been present, were not visible.

in pure culture on malt agar. As the fuscous, 2-septate, aerial spore passes through a hyaline and 1-septate stage during its development, it might be argued that it is the 'higher' type and that it is this spore which should determine primarily the genus of the fungus. On the other hand, the hyaline aquatic spores are the only ones known, so far, in nature.

I owe to Mr E. W. Mason the suggestion that, if this fungus is to be included in an existing genus, it might well find a place in *Piricularia.* The 2-septate conidia in that genus may be hyaline or fuscous. They are borne on simple erect aerial conidiophores and the production of conidia in succession resembles that in *Trichothecium roseum.* Indeed, the type species, *Piricularia grisea* (Cooke) Sacc. was originally described as *Trichothecium griseum* Cooke. There are, however, difficulties in associating the present species with *Piricularia.* Species of that genus are mostly parasites of grasses; the spore of all the described species shows a minute abscission collar, and the greatest width of the spore is near to its base and not near the middle as in my fungus.



Text-fig. 5. *Piricularia aquatica.* Aerial conidia from pure culture on malt agar. The oil-drops in the cells are shown. Fuscous cells are shaded.

Accepting Mr Mason's tentative suggestion, I am placing the fungus as a new species of *Piricularia*, although with further knowledge of aquatic Hyphomycetes, its systematic standing may have to be reconsidered.

Piricularia aquatica n.sp.

Submerged aquatic fungus with branched, septate mycelium, hyaline at first, dark olive green later. Submerged aquatic conidiophores 20–60μ long, 2–3μ broad. Aquatic conidia (aleuriospores) hyaline, lemon-shaped, 24–34μ long, 12–16μ broad, usually 1-septate near the base, rarely unequally 2-septate with the middle cell largest, containing abundant glycogen; first-formed conidium truly apical, subsequent conidia produced in succession from near the same point. Aerial conidia (aleuriospores) produced sparingly on malt agar. Aerial conidiophores straight, 40–50μ long, 2–3μ broad. Aerial conidia narrowly lemon-shaped, 24–42μ long, 8–12μ broad, greenish brown (rarely hyaline), usually 2-septate with the middle cell largest, containing numerous oil-drops; first-formed conidium truly apical, subsequent conidia produced in succession from near the same point.

On decaying leaves of *Quercus* sp. from a stream in Leicestershire, England.

Piricularia aquatica sp.nov.

Fungus aquaticus submersus, mycelio repente, ramoso, septato, primo hyalino postea olivaceo-fuscescente. Conidiophora aquatica submersa 20–60μ longa, 2–3μ lata. Conidia aquatica (aleuriosporae) hyalina, citriformia, 24–34μ longa, 12–16μ lata, plerumque prope basim 1-septata, raro inaequaliter 2-septatum, cellula media majore, abundanter glycogeno. Conidium primo evolutum apicale; conidia succedentia prope eundem locum deinceps evoluta. Conidia aeria (aleuriosporae) parce in agaro ('malt agar') evoluta. Conidiophora aeria recta, 40–50μ longa, 2–3μ lata. Conidia aeria citriformia, 24–42μ longa, 8–12μ lata, glaucobrunnea (raro hyalina), 2-septata (media cellula majore), multis guttulis oleosis praedita; conidium primo evolutum vero apicale, conidia succedentia prope eundem locum deinceps evoluta.

Hab.: in foliis putrescentibus *Quercus* sp. in fluminibus jacentibus Leicestershire, Anglia.

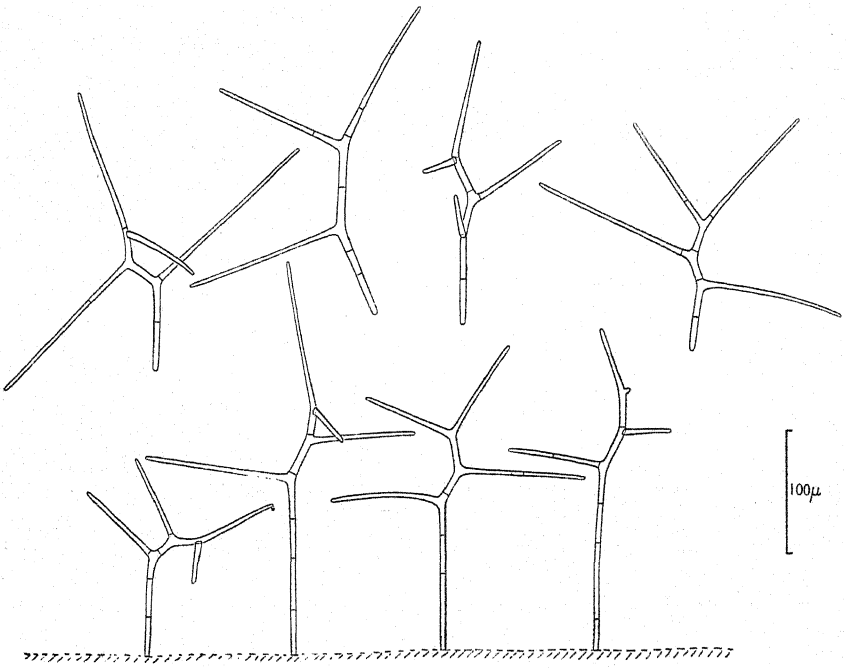
Tricladium anomalum n.sp.

This fungus (Text-fig. 6 and Pl. VI, figs. 8–10) was found growing on submerged decaying leaves of reedmace (*Typha latifolia*) in a large pond known as Puddledyke situated close to Cropston Reservoir. It was observed in three separate collections made during April 1942 and again in quantity at the end of May and in August. The only other aquatic hyphomycete noted on the leaves of reedmace was *Alatospora acuminata*.

The branched septate mycelium ramifies within the tissues of the decaying leaf and the conidiophores grow out at right angles into the water. The conidiophore is simple, 50–100μ long, 3·5–4·5μ broad and 2–3-septate. The conidium, which is of the aleuriospore type, is septate and branched, consisting of a main axis (continuous with the conidiophore) 150–250μ long, 3·5–5μ broad, and of usually three lateral branches. At the point where a lateral branch arises the main axis tends to be bent to

an obtuse angle. Each lateral is 80–120μ long, 4–5μ broad where it joins the axis, but tapers to 2–3μ at its free end. The branches usually lie in different planes. Of the very numerous spores observed, more than three-quarters were five-pronged, consisting of a main axis and three laterals, but a number were four-pronged with only two branches, and some six-pronged spores, consisting of a main axis and four laterals, were observed.

A number of single-spore pure cultures were made on malt agar. The fungus grew well on this medium, giving a mycelium of branched septate hyphae. These were hyaline at first, but soon turned brownish grey, so



Text-fig. 6. *Tricladium anomalum* n.sp. Conidia and conidiophores. In the four conidiophores figured, the junction of the conidium and the conidiophore is probably the second cross-wall below the lowest branch of the spore. No cell contents are shown. The tissue of the reedmace leaf is indicated diagrammatically.

that a colony two to three weeks old was dark brownish grey with a narrow white edging of hyaline hyphae (Pl. VI, fig. 7). There was much low aerial growth of brownish grey hyphae, giving the whole colony a fleecy appearance. This fungus did not sporulate on agar or on strips of colony immersed in water.

The fungus strongly resembles *Tricladium angulatum*. In both species, the conidium consists of a main axis, with broadly inserted laterals tapering to their extremities, usually bent to an obtuse angle at the point of origin of each lateral. There are striking differences, namely: (1) in *Tricladium anomalum* the axis of the spore normally bears three lateral branches instead

of two; (2) the spores of *T. anomalum* are much larger than those of *T. angulatum*; (3) each conidiophore is simple and appears to produce only one spore, whereas in *T. angulatum* the conidiophore is usually branched, and when unbranched the first formed conidium is truly terminal with later spores produced in succession from near the same point; (4) the culture on malt agar is brownish grey in contrast to the white colonies of *T. angulatum*; and (5) a strip of colony fails to sporulate in water, but a similar strip of *T. angulatum* produces abundant spores in water.

I have no doubt that this species is quite distinct from *T. angulatum*, but it is regarded as co-generic with that species in spite of the additional arm on the spore.

Tricladium anomalum n.sp.

Submerged aquatic fungus with branched, septate mycelium, hyaline at first but dark later. Conidiophores simple, erect, 50–100 μ long, 3·5–4·5 μ broad. Conidia (aleuriospores) apical, branched, septate, hyaline; main axis 150–250 μ long, 3·5–5 μ broad; branches usually three (rarely two or four), arising separately with intervals of 20–30 μ, 80–120 μ long, 4–5 μ broad at the base and not constricted, tapering to 2–3 μ at the apex; main axis usually curved or bent to an obtuse angle at the point of origin of each branch.

On submerged decaying leaves of *Typha latifolia* from a large pond in Leicestershire, England.

Tricladium anomalum sp.nov.

Fungus aquaticus submersus, mycelio repente, septato, ramoso, primo hyalino, postea fuscescente. Conidiophora simplicia, erecta, 50–100 μ longa, 3·5–4·5 μ lata. Conidia (aleuriosporae) acrogena, ramosa, septata, hyalina; ramus principalis 150–250 μ longus, 3·5–5 μ latus; ramuli secundarii plerumque tres (raro duo vel quatuor), separatim orientes, intervallis 20–30 μ, 80–120 μ longi, basi 4–5 μ non constricti, apice ad 2–3 μ attenuati; ramus principalis plerumque curvulus vel iisdem locis e quibus ramuli secundarii oriuntur obtuse angulatus.

Hab.: in foliis putrescentibus *Typhae latifoliae* in lacu, Leicestershire, Anglia.

Distribution of aquatic Hyphomycetes

My observations on aquatic Hyphomycetes have been limited, so far, to the immediate neighbourhood of Cropston in Leicestershire, but it is of interest to know if they are of wide occurrence. Unfortunately it has not been possible to undertake a general investigation of their distribution. However, during April 1942, a collection of submerged decaying leaves of oak and sweet chestnut was made from a small stream near Westerham in Kent. These leaves yielded the following species: *Clavariopsis aquatica*, *Tetracladium Marchalianum*, *Piricularia aquatica*, *Tricladium splendens*, *T. angulatum*, *Anguillospora longissima*, *Lemonniera aquatica*, *Alatospora acuminata*, *Heliscus longibrachiatus* and *Tetrachaetum elegans*.

Again, in August 1942, a collection of submerged decaying leaves of hawthorn was made from a stream in Skeffington Wood in east Leicester-

shire about ten miles from Cropston. These leaves were brown, but had not become lacunate by decay. The following seven species occurred in abundance on all the leaves examined: *Lemonniera aquatica*, *Anguillospora longissima*, *Clavariopsis aquatica*, *Tetracladium Marchalianum*, *Alatospora acuminata*, *Tricladium angulatum* and *Flagellospora curvula*.

These isolated observations strongly suggest that these fungi are widely distributed. It would be surprising if further observations do not show that many of these Hyphomycetes are very common on the decaying submerged leaves of trees and shrubs.

Summary

Of the sixteen species of aquatic Hyphomycetes previously described from decaying alder leaves (Ingold, 1942), thirteen are now recorded on decaying submerged oak leaves. In addition two new species, *Dendrospora erecta* n.gen., n.sp. and *Piricularia aquatica* n.sp., are described. These are regular members of the aquatic oak-leaf flora of the streams in Swithland Wood during the spring.

Tricladium anomalum n.sp. is described growing on decaying submerged leaves of *Typha latifolia* from a pond.

The distribution of aquatic Hyphomycetes is briefly discussed, and it is suggested that they are probably very common on submerged decaying leaves of trees and shrubs.

My best thanks are due to Miss E. M. Wakefield for her kindness in helping me with the Latin diagnoses.

Reference

Ingold, C. T. (1942). Aquatic Hyphomycetes of decaying alder leaves. *Trans. Brit. myc. Soc.* xxv, 339–417.

Explanation of Plates V and VI

Note. All the photographs are from living unstained specimens with the exception of Pl. VI, fig. 4.

Plate V. *Dendrospora erecta* n.gen., n.sp.

Fig. 1. Conidiophore with young developing spore. The cross-wall separating the conidium and the conidiophore is indicated by the arrow. × 280.

Fig. 2. A single mesh in the vein network of an oak-leaf skeleton showing a conidiophore. Without further growth the conidium separated from the conidiophore at the point shown by the arrow. × 92.

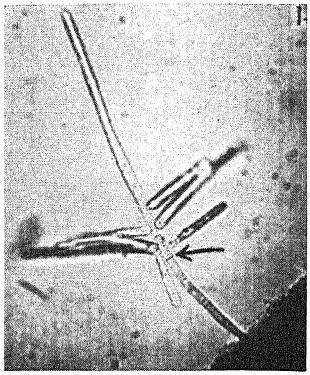
Fig. 3. Conidiophore bearing a ripe spore. Where the main axis of the spore joins the conidiophore is indicated approximately by the arrow, but the actual junction is obscured by the branches of the spore. Note the lateral branch produced by the conidiophore. No other branched conidiophore has been observed. × 140.

Fig. 4. Spore. × 137.

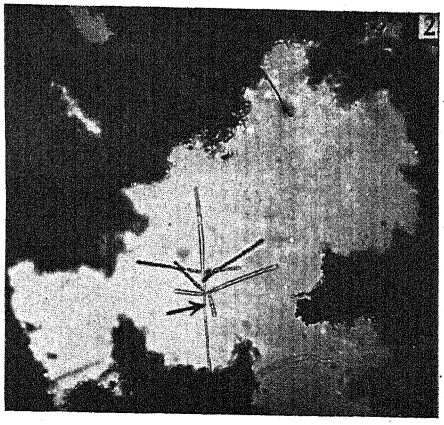
Fig. 5. Conidiophore with young developing spore in which the main axis and the branches have probably not reached half their final length. The arrow shows the junction of the conidiophore and spore. × 300.

Figs. 6, 7. Photograph and camera lucida drawing of the same spore. The photograph was taken after making the drawing and when the spore had been flattened into a single plane by pressure of the cover-glass. Corresponding branches in the two figures have been given the same numbers. The primary branches are indicated by Roman figures (I–VIII), and the secondary ones by ordinary figures. Thus 3*a* and 3*b* are branches of III. × 185.

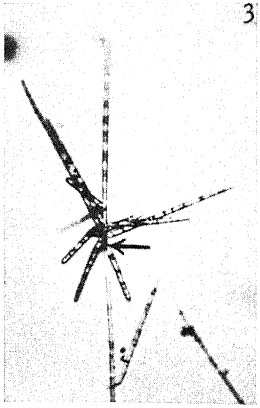
1



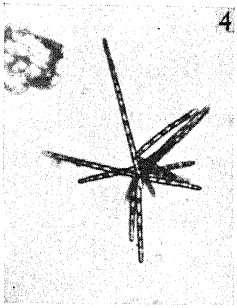
2



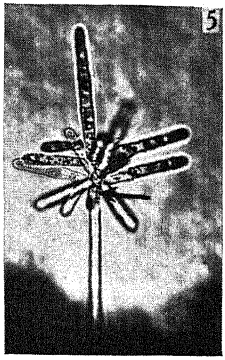
3



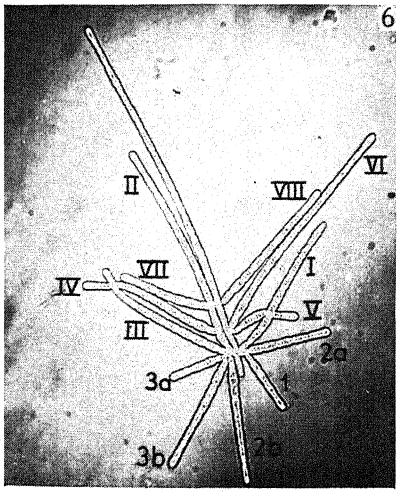
4



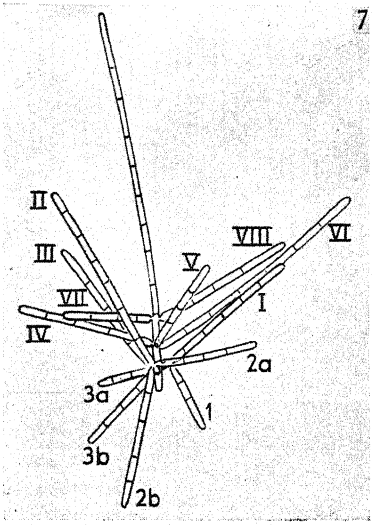
5

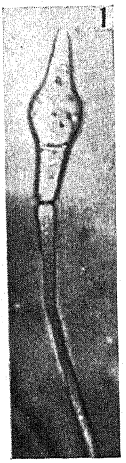


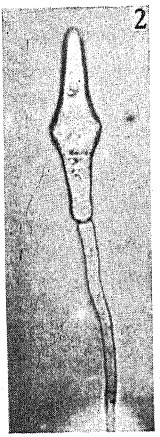
6

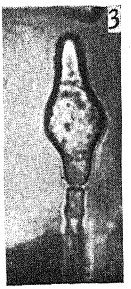

II
VIII
VI
IV
VII
I
III
V
2a
3a
1
3b
2b

7


II
III
VIII
VI
V
VII
I
IV
2a
3a
1
3b
2b

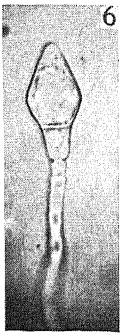

1

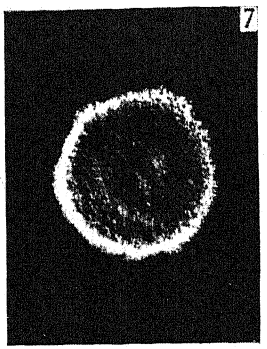

2

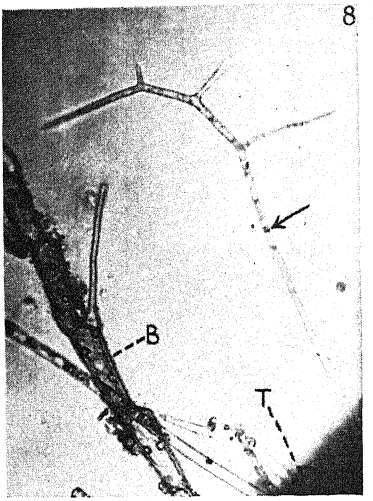

3

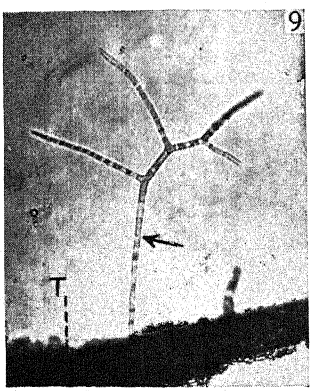

4


5


6


7


8
B
T


9
T

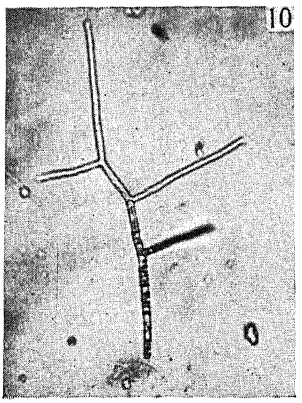

10

PLATE VI

Figs. 1, 2. *Piricularia aquatica* n.sp. Aquatic conidiophores, with ripe conidia, developed from strips of pure culture submerged in water. × 532.

Figs. 3–6. *Piricularia aquatica*. Aquatic conidiophores, with ripe conidia, developed on submerged decaying oak leaves. The specimen shown in Fig. 4 was stained with iodine which gives a deep chestnut brown (black in the photograph) with the glycogen of the spore. Figs. 3 and 5, × 545; Fig. 4, × 490; and Fig. 6, × 525.

Fig. 7. *Tricladium anomalum* n.sp. Pure culture three weeks old grown on malt agar at 16–18° C. Natural size, photographed with reflected light.

Fig. 8. *Tricladium anomalum*. Conidiophore with developing conidium. The arrow shows the junction of the conidiophore and the conidium. '*T*' is part of the decaying reedmace leaf; '*B*' is a filament of the alga *Bulbochaete* sp. growing epiphytically on the reedmace leaf. × 200.

Fig. 9. *Tricladium anomalum*. Conidiophore with a nearly ripe conidium growing on a decaying leaf of reedmace (marked '*T*'). The arrow shows the junction of the conidium and its conidiophore. × 185.

Fig. 10. *Tricladium anomalum*. Conidium. × 185.

(*Accepted for publication* 24 *August* 1942)

A DISEASE OF LILIES CAUSED BY *FUSARIUM BULBIGENUM* COOKE & MASS.

By LILIAN E. HAWKER and B. SINGH, *Department of Mycology and Plant Pathology, Imperial College of Science and Technology, London*

I. Introduction

In the summer of 1939 serious losses occurred among seedling lilies of various varieties at a nursery where lilies are grown in large quantities. Bare patches developed in boxes of one-year-old plants, and the plants bordering these patches had yellow, stunted foliage. Isolations from diseased plants invariably yielded a species of *Fusarium*.

No record has been found of a similar disease of seedling lilies, but species of *Fusarium* have been reported in association with diseases of mature plants. Thus *Fusarium Solani* (Mart.) App. & Wollenw. was isolated by van Hell (1931) from diseased roots and bulbs of lilies in Holland, but inoculation experiments gave negative results and he attributed the disease to *Cylindrocarpon radicicola* Wollenw. A root-rot of lilies caused by *Fusarium* was reported from America by Charles and Martin (1928) and by Slate (1936). More recently, Imle (1940) described a basal rot of bulbs of *Lilium candidum* and *L. testaceum* imported into the U.S.A. He isolated *Fusarium* from brown, rotted areas at the bases of the bulb scales.

II. Disease symptoms

Seedlings of *Lilium auratum*, *L. Sargentiae*, *L. nobilissimum* and a hybrid lily from the edges of bare patches in the seed boxes were obtained from the nursery. The first sign of infection was a slight wilting of the leaves. Wilted seedlings had rooted well and had formed small sound bulbs, but the roots showed a reddish brown rot which usually began at the tips. Seedlings in which the disease was more advanced bore yellow, stunted foliage. The roots were entirely rotted and the rot was spreading from the roots into the bulb scales. The junction between diseased and healthy tissue was clearly defined, the lower portions of the scales being completely rotted while the upper parts were white and sound. Hence infected scales readily became detached from the bulbs. The outer scales were attacked first. Some bulbs were wholly rotten. If diseased tissues were kept in a moist atmosphere a white mycelium bearing spores of *Fusarium* developed.

Reddish brown lesions occurred on the bulb scales, roots and the underground parts of the main stems of mature plants of *Lilium regale*, grown at the Imperial College Biological Field Station at Slough, and on bulbs of a hybrid lily stored at the nursery.

III. Isolation and identification of pathogen

Fusarium was obtained from each of 125 isolations made from diseased roots and bulbs of seedlings of various species, from bulbs, roots and stems of mature plants of *Lilium regale*, and from bulbs of a hybrid lily. A few bulbs also gave species of *Phytophthora*, *Penicillium*, *Rhizoctonia*, and *Trichoderma*.

All the isolates of *Fusarium* were morphologically similar, and a detailed study was made of a strongly pathogenic one from a damped-off seedling of *Lilium auratum*.

(*a*) *General cultural features*

Aerial mycelium typically well developed; loose cottony; colour varying from white to pink thus:

Potato agar: usually lacking.
Cornmeal agar, Oatmeal agar, Malt agar } pink to bluish pink.
Cornmeal agar + 1·5 % dextrose: deep blood-red.

Sclerotia noted on potato agar, oatmeal agar, Brown's medium and potato plugs; white or buff when young sometimes bluish later; diameter 1–3 mm.; generally distributed, but in old dried-up cultures particularly abundant along the line of contact of medium with culture tube; occasionally in cluster of 2–4 mm. diam.

Sporodochia abundant on oatmeal and potato plugs three weeks after inoculation; size 0·5–2·0 mm. diam.; slimy, buff coloured, becoming darker when older; sometimes formed in clusters of two or three.

In an old culture sectoring had taken place. The saltant produced very little mycelium and sometimes no aerial growth, and was less pathogenic than fresh isolations.

Optimum temperature for growth was approximately 30° C.

(*b*) *Microscopic features*

Microconidia, more abundant than macroconidia both in culture and on bulb; formed abundantly in aerial mycelium and in medium in false heads (*Cephalosporium*); 0–1 septate, oval or slightly curved, apedicellate.

Dimensions: 0-septate 2·8–18·5 × 2·5–3·7 μ, av. 7·4 × 3·1 μ;

one-septate 10·2–27·8 × 2·5–3·7 μ, av. 14·9 × 3·1 μ.

Macroconidia formed sparingly in mycelium in small pionnotes on potato and malt-agar media or in sporodochia on oatmeal agar; mostly three-septate, pedicellate, curved, terminal cell curved and somewhat constricted, tendency to degeneration in form; in young sporodochia (i.e. up to 0·5 mm. diam.) 90–95 % of macroconidia three-septate, remainder

four- to five-septate; in older sporodochia number of three-septate spores decreased to 80 %, remaining 20 % four- to five-septate.

Dimensions: three-septate 22·2–42·6 × 2·8–4·6 μ, av. 36 × 3·8 μ;
four-septate 33·3–44·4 × 2·8–4·6 μ, av. 38·7 × 3·8 μ;
five-septate 37–48·2 × 2·8–4·6 μ, av. 44·1 × 4·1 μ.

Chlamydospores formed in abundance on potato and oatmeal agars both in medium and on aerial mycelium, singly or in chains, not found in the bulb; in old sporodochia chlamydospores formed from segments of macroconidia.

Dimensions: 7·4–14·8 × 5·6–12·9 μ, av. 9·4–8 μ.

The presence of terminal and intercalary chlamydospores and abundant microconidia and the shape of the macroconidia indicate that this species of *Fusarium* should be placed in the section *Elegans*.

A strain of *Fusarium bulbigenum* Cooke & Mass. isolated from a *Narcissus* bulb with basal rot, resembled the strain under consideration. The resemblance of the latter to *Fusarium bulbigenum* described in Wollenweber's monograph (1935) suggested that it was probably a strain of that species. Miss E. M. Wakefield has kindly confirmed this identification.

IV. Inoculation experiments

Inoculation experiments were made with the strain of *Fusarium* from *Lilium auratum*. *Fusarium bulbigenum* isolated from *Narcissus* was included for comparison. In one series of experiments, roots, bulb scales and whole bulbs of *Lilium regale* and seedlings of *L. Wilmottiae* were inoculated, either by wounding or by contact, with agar inocula. In a second series seeds were sown and bulbs planted in soil contaminated with the *Fusarium*.

(*a*) *Inoculation with agar inocula*

Healthy bulbs of *Lilium regale* and of *Narcissus* var. Golden Spur were washed with 95 % alcohol, soaked for ten minutes in a 0·1 % solution of mercuric chloride, and finally washed in sterile water. Scales cut from healthy bulbs of *Lilium regale* and of *Narcissus* and pieces cut from healthy roots of *Lilium regale* were similarly treated (with the exception that roots were soaked in mercuric chloride for three minutes) and the cut ends were sealed with paraffin wax. Seedlings of *L. Wilmottiae* were washed in several changes of sterile water. These were then inoculated by placing a small piece of an agar culture either on the unwounded surface or in a wound which was sealed with wax. Small pieces of sterile agar were always applied as controls. These controls all gave negative results and are not included in the table. The inoculated material was kept moist for two to three weeks, or longer with whole bulbs, in a heated greenhouse, or in an incubator at 20° C. The results are given in Table 1.

Heavy infection followed when either the strain of *Fusarium bulbigenum* from lily or that from *Narcissus* was introduced into wounds in the surface

of whole bulbs or of isolated bulb scales of either *Lilium regale* or *Narcissus* or seedling bulbs of *Lilium Wilmottiae*. No infection of unwounded bulb scales took place. Both fungi penetrated unwounded roots of *L. regale* and of seedlings of *L. Wilmottiae*. *Fusarium bulbigenum* from lily penetrated unwounded seedlings of *Lilium Wilmottiae* at the junction of root and bulb, probably entering through the roots. The strain from *Narcissus* did not attack such seedlings but the number of trials was small. This fungus was always less pathogenic to lilies than was the strain isolated from *Lilium auratum*, for rotting due to the former was much slower than that due to the lily strain. The strain from lilies was less pathogenic to *Narcissus* than was the strain from that host.

Table 1

Material inoculated	Method of inoculation	*F. bulbigenum* from lily: No. inoc.	*F. bulbigenum* from lily: No. infected	*F. bulbigenum* from *Narcissus*: No. inoc.	*F. bulbigenum* from *Narcissus*: No. infected
L. regale, bulbs	Wound	60	55	44	40
	Contact	14	0	7	0
Narcissus, bulbs	Wound	61	41	21	21
	Contact	14	0	7	0
L. regale, bulb scales	Wound	29	27	18	18
	Contact	9	0	7	0
Narcissus, bulb scales	Wound	32	29	16	16
	Contact	14	0	7	0
L. regale, roots	Wound	8	8	5	5
	Contact	6	6	3	3
L. Wilmottiae, seedling, bulbs	Wound	20	20	4	4
	Contact	16	0	8	0
L. Wilmottiae, seedling, roots	Wound	16	16	4	4
	Contact	24	21	12	8
L. Wilmottiae, seedling, junction of roots and scales	Wound	8	8	4	4
	Contact	8	5	4	0

Table 2

Variety of lily	Soil	No. of seeds sown	Condition 6 months after sowing: No. healthy plants	No. slightly attacked *Fusarium*	No. severely attacked *Fusarium*
L. Wilmottiae	Autoclaved	40	27	1	0
	Infected*	40	8	3	5
L. dauricum	Autoclaved	40	30	1	3
	Infected*	40	6	6	6
L. Davidii	Autoclaved	40	21	0	0
	Infected*	40	8	3	6

* 3 parts autoclaved soil + 1 part soil from bare patch in seed box.

(*b*) *Soil inoculation*

(i) *Addition of naturally infected soil*

Soil from around diseased seedlings in seed boxes at the nursery was sifted to remove plant debris, mixed with three volumes of autoclaved soil and sown with lily seeds. The results of one such experiment are set out in Table 2 and show that the fungus was present in the soil. Other ex-

periments in which the soil inoculum was added to autoclaved soil or to unsterilized compost gave comparable results.

(ii) *Addition of fungal cultures to the soil*

Experiments were carried out in which seeds of *Lilium Wilmottiae*, *L. dauricum* and *L. Davidii* were sown in soil which had been inoculated with *Fusarium bulbigenum* isolated from lily seedlings or from *Narcissus* bulbs.

The fungi were grown for fourteen days at 20° C. on a mixture of sand and cornmeal (sand, 95 g.; cornmeal, 5 g.; water, 20 c.c.) in sterile plugged flasks. The cultures were then added to autoclaved potting compost at the rate of 2·5 g. to every 100 g. of soil. A similar quantity of sterile sand was added to autoclaved compost for control. Fifteen or occasionally ten seeds were sown in each 4 in. pot. Each experiment was replicated

Table 3

Strain of *F. bulbigenum* added to autoclaved soil	No. of seeds sown	No. germinated	No. subsequently damped-off	Percentage survivors
None	150	149	0	99·3
Fresh isolation, lily	150	114	72	28
Old isolation, lily	150	136	31	70
Fresh isolation, *Narcissus*	150	138	19	79·4

Table 4

Variety of lily	Strain of *F. bulbigenum* added to autoclaved soil	No. seeds sown	No. germinated	No. damped-off	% healthy plants of seeds sown
L. Wilmottiae	None	690	446	5	63·5
	Fresh isolation, lily	270	78	64	5·2
	Old isolation, lily	450	197	76	27·0
	Fresh isolation, *Narcissus*	150	95	18	51·3
L. dauricum	None	640	500	3	77·7
	Fresh isolation, lily	595	206	131	12·6
	Old isolation, lily	400	278	77	50·3
L. Davidii	None	565	420	13	72·1
	Fresh isolation, lily	595	131	112	3·4
	Old isolation, lily	300	149	54	31·7
	Fresh isolation, *Narcissus*	185	162	36	68·1
	Isolation from mature bulb, *L. regale*	150	64	6	38·7

ten times. The experiments were made in a heated greenhouse during the period September–April and in an unheated frame during the summer. The duration of individual experiments varied from ten to twenty-four weeks. The results of an experiment with seeds of *Lilium dauricum* are shown in Table 3 which gives the number of survivors eleven weeks after inoculation.

Additional experiments, which are summarized in Table 4, give essentially similar results. In a number of these the addition of a fresh isolate to the soil caused a much higher proportion of pre-emergence damping-off than in the experiment of Table 3. This may have been because the soil was kept rather wet in some of the earlier experiments. In all the experiments, however, the number of survivors in the presence of a recently isolated culture was small. Virulence decreased in culture.

In a single experiment with seeds of *Lilium Davidii* a strain from a mature bulb of *L. regale* caused losses equivalent to those due to an old isolation from seedlings. *Fusarium bulbigenum* recently isolated from *Narcissus* bulbs was also pathogenic but to a smaller degree than the strain from lily.

In three experiments, mature bulbs of *Lilium regale* were planted in the open over sand to which a sand and cornmeal culture of *Fusarium bulbigenum* from lily had been added. Control bulbs were planted over clean sand. In each experiment the shoots produced by the inoculated plants were slightly shorter and less vigorous than those from the controls. When the bulbs were lifted in autumn the roots of the inoculated ones were rotten at the tips while the outer bulb scales showed reddish brown lesions. *F. bulbigenum* was isolated from these. Rotting did not progress during storage and the bulbs were planted in clean soil after removal of the infected scales. The plants produced were healthy but smaller than those from the control bulbs. The presence of similar lesions yielding *F. bulbigenum* on mature bulbs of *Lilium regale* grown at Slough and of a hybrid lily grown at a nursery shows that slight infection of mature bulbs does occur under natural conditions. While the fungus does not kill the mature plant it is clear that a significant loss of vigour follows attack.

(iii) *Watering with spore suspensions*

Losses at the nursery where the disease was first observed took place chiefly among one-year-old seedlings. The seeds were sown in steam-sterilized soil, which was stored for several months after sterilization, during which time it might have become reinfected. It was unlikely, however, that there was an initial concentration of the fungus in the seed boxes comparable with that in the experiments described above. These seed boxes were watered from storage tanks underneath the benches, and this may have been the source of contamination. One would expect some time to elapse before much infection of the soil would develop from this source.

Six boxes of autoclaved soil were each sown with 125 seeds of *L. Wilmottiae*. Three of these were sprayed with a suspension of spores of *Fusarium bulbigenum* immediately after sowing and again after five and eleven weeks. All the boxes were watered with tap water. Six months after sowing the seedlings were examined. The three control boxes contained 285 seedlings, one of which was diseased, while in the inoculated lots there were 213 seedlings, forty-nine of which were diseased (i.e. 75·7 % of the seeds sown in the control boxes and 43·7 % of those in the inoculated lots produced healthy seedlings). These results were confirmed by a number of small-scale experiments.

In another series of experiments, seeds were sown in autoclaved soil and the seedlings were pricked out into unsterilized compost or autoclaved soil when the second foliage leaf had just uncurled. These were later inoculated by watering with spore suspension. In one such experiment seedlings of *Lilium Wilmottiae*, *L. dauricum* or *L. Davidii* were planted in autoclaved soil in well-drained sterilized tins. Half of these were watered with tap water only. The results with the three varieties were similar and will be given

collectively. Of sixty-six control plants, sixty-two were healthy after four months (four having been eaten off by slugs) while only eighteen out of sixty-six were healthy in the inoculated lots, the rest being more or less severely attacked by *Fusarium*. The other experiments in this series all gave comparable results.

Thus it is obvious that contamination of the water supply can cause infection and produce much loss during the long period (up to twenty-one months) that the seedlings remain in the seed boxes. It is unlikely, however, that the amount of contamination would be as great as that in the experiments described above, and losses from this source should be controlled by periodic cleaning of the water tanks and by covering them to prevent contamination from the benches.

V. Control measures

In the opinion of the grower concerned, losses were highest in the houses which were kept at a relatively high temperature. This was confirmed by a small-scale experiment at Slough and is comparable to the behaviour of *Fusarium bulbigenum* on *Narcissus* which was shown to cause heavier losses at a relatively high temperature (Gregory, 1932; Hawker, 1935, 1940). Although losses were less at a low temperature they were not negligible, for severe loss occurred in cold frames. Moreover, any reduction in the temperature of the houses is undesirable because it retards the lilies. Attempts were therefore made to control the disease by means of fungicides.

(*a*) *Formalin dust in seed boxes*

Since possible sources of infection were incomplete sterilization or recontamination of the soil used to fill seed boxes or frames, the effect of the addition of a fungicide to the soil was examined. As it was difficult to obtain large quantities of lily seed it was not possible to compare the effects of a wide range of fungicides. In a preliminary experiment, formalin dust was compared with an organic mercury fungicide. The former was greatly superior and was used in all subsequent experiments.

Three parts by volume of autoclaved soil were mixed with one part each of peat and sand. This was inoculated by adding a small quantity of naturally infected soil or of a sand and cornmeal culture of *Fusarium bulbigenum* (prepared as described in the previous section) and was stored for at least one month before the addition of the fungicide. In earlier experiments formalin dust was prepared after the formula of Alexander, Young and Kiger (1931) by adding fifteen parts by weight of commercial formalin (40 % formaldehyde) to eighty-five parts of 1:2 mixture of kaolin and diatomaceous earth. (This preparation had been used successfully by Tandon (1939) in the control of a damping-off disease of tomatoes.) In later experiments the method was simplified by using air-dried soil as absorbent. In all experiments 0·5 % by weight of the formalin dust was added to the inoculated compost. This was thoroughly mixed and put into pots or boxes which were sown two days later and stored either in a heated

greenhouse or in a cold frame. The results of a typical experiment are given in Table 5. Other experiments all gave comparable results.

Table 5

Variety used	Soil treatment	No. of seeds sown	Total germinated	No. diseased	% clean seedlings of seeds sown
L. Davidii	Compost*	120	96	0	80
	Compost* + *F. bulbigenum*	120	36	30	5
	Compost* + *F. bulbigenum* + formalin dust	120	97	19	65
L. Wilmottiae	Compost*	120	73	2	60·9
	Compost* + *F. bulbigenum*	120	11	8	2·5
	Compost* + *F. bulbigenum* + formalin dust	120	60	9	42·5

* Autoclaved soil + peat + sand.

Thus formalin dust gave good but not complete control. It is unlikely that the contamination of the seed boxes prepared by the methods in use at the nursery would be as heavy as that in the experimental boxes, and then the degree of control might well be adequate.

A small-scale experiment was also set up at the nursery. Five seed boxes were prepared in the usual manner by the nurseryman. Three were left untreated, while 0·5 % formalin dust was thoroughly mixed with the soil of the other two. All were sown with seeds of *Lilium auratum* a few days later (July 1939). The seeds germinated well in all boxes, but by the early summer of 1940 the treated ones showed a denser stand with larger leaves. In October 1940 the grower reported that 'the foliage on the two treated boxes was twice as large and plentiful as on the other boxes'. The foliage later died down naturally and the boxes were turned out early in 1941. It was not possible to obtain detailed results without interfering unduly with the grower's routine but some observations and counts were recorded. The bulbs from the two treated lots were much more numerous, bigger and better rooted than those from the untreated lots. The treated boxes were very similar, and one which was examined in detail contained 355 bulbs (one of which was slightly diseased) weighing 728 g. The roots of all the sound bulbs were white and healthy. The three untreated boxes were much less uniform. The worst and the best of these contained respectively fifty-eight bulbs (seven diseased) weighing only 77 g. and 102 bulbs (ten diseased) weighing 196 g. Hardly any of these had entirely unattacked roots, whilst the compost contained much rotten debris from badly diseased bulbs which had broken up owing to the destruction of the bases of the scales by the fungus. The grower pointed out that the treated boxes were overcrowded and would have probably yielded better results if they had been sown more thinly than was customary. This suggests that thin sowing on treated soil may lead to economy in the use of valuable seed. It seemed likely that infection at this nursery was usually due either to incomplete soil sterilization or to slight recontamination before sowing. The use of formalin dust promised to give good control there, but the

experiment could not be repeated the following year because the houses were required for food production.

(*b*) *Liquid formalin in frames*

Large quantities of lilies were raised from seed in cold frames at the nursery. Steam sterilization of the soil in these frames was less efficient than in seed boxes, and losses from *Fusarium* were heavy. The grower considered that the use of formalin dust on this scale would require too much labour. Therefore the efficacy of liquid formalin was tested. A small frame at the Field Station was contaminated with a sand and cornmeal culture of *Fusarium bulbigenum* and another was filled with compost brought from a frame at the nursery where the disease had been rampant. Half of the first frame was treated with commercial formalin (40 % formaldehyde) at the rate of 1 c.c. per 25 sq. cm. early in March and covered for several days. The frame was sown with seeds of *Lilium dauricum* one week later. The seeds in the treated half were a few days later in germinating than those in the control part, but by mid-June the former were green and healthy while the latter were dying as a result of attack by *Fusarium*. Later, the foliage of both lots was severely damaged by *Botrytis*. In the following March the bulbs were lifted. The treated half yielded fifty-six bulbs, eleven of which were slightly diseased while the control half yielded only fourteen bulbs all of which were more or less severely rotted. Half of the second frame was treated with formalin at twice the above rate (i.e. 2 c.c. per 25 sq. cm.) in July, and sown with seeds of *Lilium regale* one week later. By September the treated half showed a distinctly better stand than the untreated half. In the following March* eighty-five seedlings, three of which were slightly diseased, were lifted from the treated part while the control part yielded sixteen seedlings, six of which were diseased. Thus some protection was obtained by the use of liquid formalin in frames containing heavily contaminated soil, and it is possible that more satisfactory results could be obtained by the use of a greater quantity of formalin applied some time before sowing. Further experiments were prevented by war conditions.

(*c*) *Watering with fungicides*

Owing to the length of time that lily seedlings remain in the seed boxes or frames, severe losses may easily follow if the soil be accidentally re-contaminated. An attempt was made to prevent losses by watering with weak fungicidal solutions.

In one series of experiments seeds were sown or seedlings pricked out in autoclaved soil mixed with clean sand and peat. When the seedlings were established they were watered with a suspension of spores of *Fusarium bulbigenum*, or infected soil was sprinkled around them. After an interval of from two days to one month they were watered with a weak fungicidal

* Seedlings of *L. regale* are normally lifted in late autumn, but the frame used here was required for other purposes. It is unlikely that any of the control plants would have survived until November.

solution. Formalin was useless when used in this way, and a 0·02 % solution of the proprietary mercuric fungicide 'Uspulun' was used in most experiments. The results of two small-scale experiments in which some protection was obtained by six weekly applications of Uspulun are given in the first five lines of Table 6. Other small-scale experiments confirmed this result, but an experiment on a larger scale was spoiled by *Botrytis* before the boxes were turned out. Before this attack, however, the stand in the Uspulun-treated boxes was much denser than that in the controls.

Table 6

Source of infection	Treatment	No. of seeds or plants	No. clean plants	No. diseased plants
Infected soil	None	100 seeds	49	28
	6 weekly applications of 0·02 % Uspulun	100 seeds	70	6
None	None	66 plants	62	0
Spore suspension	None	66 plants	18	28
	6 weekly applications of 0·02 % Uspulun	66 plants	59	2
Infected soil	None	125 seeds	10	6
	2 applications of 0·02 % Uspulun (5 l. to 1500 sq. cm.)	125 seeds	36	0
	Treated formalin before planting	125 seeds	82	3
	Treated formalin before planting + 2 applications of 0·02 % Uspulun	125 seeds	85	2

In the second of the two experiments described in the previous section half of the untreated and formalin-treated areas were watered with Uspulun after the seeds had germinated. Some protection was obtained (last four lines of Table 6), but this was not so good as with formalin treatment before sowing, while watering with Uspulun did not increase the efficacy of the formalin treatment.

A large-scale experiment was also made at the nursery. A range of fifteen cold frames showed a poor stand of one-year-old seedlings of *Lilium regale*. All the frames were well watered with tap water and six were then given 1 pint per sq. ft. of a 0·02 % solution of Uspulun. The disease was established before treatment, but when the seedlings were dug six months later the treated lots were slightly better. The bulbs were cleaned and divided by the grower into good and bad lots, the latter including both diseased and very small bulbs. These were counted and weighed. The average number of bulbs from the six treated frames was 286 (wt. 1223·8 g.), of which 235 (wt. 1027·5 g.) were classed as good while the average yield from the nine untreated frames was 204 bulbs (wt. 989·4 g.) of which 156 (wt. 745 g.) were classed as good.

Thus the use of formalin dust in the seed boxes gives good control of the disease, while the use of liquid formalin in the frames and occasional watering with a weak solution of Uspulun during the growing period offer further promising methods of control.

VI. Summary

A disease of seedling lilies was found to be due to *Fusarium bulbigenum* Cooke & Mass. Disease symptoms and the morphology of the pathogen are described in detail. A similar fungus was isolated from lesions on mature bulbs.

Inoculation experiments showed that the fungus can enter unwounded roots of *Lilium regale* and of seedling lilies but cannot penetrate unwounded bulb scales. A strain of *Fusarium bulbigenum* from *Narcissus* caused rotting of wounded bulb scales but rotting was slower than with the lily strain.

A high incidence of both pre-emergence and post-emergence damping-off of lily seedlings occurred in autoclaved soil contaminated by soil from the vicinity of diseased seedlings or by sand and cornmeal cultures of *Fusarium bulbigenum*. The strain from *Narcissus* caused less heavy losses. Old isolations of the lily strain were less virulent than fresh ones.

Watering the seed boxes with a suspension of spores of *Fusarium bulbigenum* caused losses.

The addition of a formalin dust to the seed boxes before sowing gave good control. Watering the soil in frames with liquid formalin before planting, or watering the growing seedlings with a weak solution of Uspulun gave some control.

References

Alexander, L. J., Young, H. C. & Kiger, C. M. (1931). Causes and control of damping-off of tomato seedlings. *Bull. Chicago agric. Exp. Sta.* no. 496, pp. 1–38.

Charles, V. K. & Martin, G. H. (1928). Some diseases of lilies. *Plant Dis. Reptr*, xii, 82.

Gregory, P. H. (1932). The *Fusarium* bulb rot of *Narcissus*. *Ann. appl. Biol.* xix, 475–514.

Hawker, L. E. (1935). Further experiments on the *Fusarium* bulb rot of *Narcissus*. *Ann. appl. Biol.* xxii, 684–708.

Hawker, L. E. (1940). Experiments on the control of basal rot of *Narcissus* bulbs caused by *Fusarium bulbigenum* Cke. & Mass. *Ann. appl. Biol.* xxvii, 205–17.

Hell, W. F. van (1931). Onderzoekingen over ziekten van lelies. Thesis, 116 pp. Baarn: Hollandia-Drukkerij, N. V.

Imle, E. P. (1940). A bulb disease of lilies caused by *Fusarium* spp. (Abstract) *Phytopath.* xxx, 11.

Slate, G. L. (1936). Diseases among the lilies. *Horticulture*, xiv, 96–7.

Tandon, R. N. (1939). Control of damping-off of tomatoes. Thesis for the degree of Ph.D. in the University of London, 41 pp.

Wollenweber, H. W. (1935). *Die Fusarien: ihre Beschreibung, Schadwirkung und Bekampfung.* 355 pp. Berlin.

(*Accepted for publication* 6 *August* 1942)

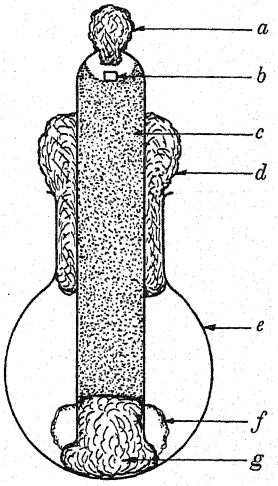
METHODS FOR OBTAINING FRUCTIFICATIONS OF WOOD-ROTTING FUNGI IN CULTURE

By E. C. BADCOCK, *Forest Products Research Laboratory, Department of Scientific and Industrial Research*

(With Plate VII and 1 Text-figure)

In 1941 I described a medium consisting of sawdust to which various nutrients were added, on which many wood-rotting fungi make exceptionally vigorous growth. The formation of fructifications was noted in eight of the twenty species listed. Since then, by using the methods described below, six more of the species there listed, together with sixty-seven additional species, have fruited on the sawdust medium. Many of these fungi have not previously fruited on other media in this laboratory.

It had been observed that in cultures of *Polystictus versicolor*, *Trametes serialis* and *Fomes pinicola* growing in large tubes almost completely filled with the sawdust, the mycelium would grow through the plugs and begin to form fructifications, if the tubes were kept in a metal-lined incubator in which a fairly high relative humidity was maintained. This suggested that it might be desirable to maintain around the mouth of the tube a relative humidity rather higher than is normally present in the laboratory. For the formation of normal fructifications, it is necessary in most species to expose the cultures to light for considerable periods, and this is not readily achieved in an incubator. Moreover, contamination of the plugs with moulds sometimes occurred in the incubators, so the following method was devised which keeps the plugs sterile and reproduces the humid conditions of the incubators.



Text-fig. 1.

Text-fig. 1 shows the general arrangement of the culture vessel. *c* is a boiling tube in which a small hole has been blown in the bottom—the tube is packed rather firmly with the sawdust medium and then plugged with cotton wool in the usual way, the small hole also being plugged: the tube is then placed with the open end in a wide-mouthed flask *e*, in which there is a pad of wet absorbent cotton wool. The space in the neck of the flask around the tube is filled with a cotton-wool plug *d*. The apparatus is then sterilized in an autoclave for 30 min. The transplant of fungus mycelium is introduced through the small hole and the small cotton-wool plug sealed down with a little plasticine to prevent drying out, and to prevent the fungus growing out at this end. The mycelium grows along the tube

through plug *G* and fructifications usually develop around the mouth of the tube within the flask. In this way the developing fructification is kept in a relatively moist, but not saturated, atmosphere without risk of contamination. This method is very satisfactory for producing fruit bodies of *Trametes serialis*.

Some fungi do not form mature fruit bodies in a confined space such as the flask described above, possibly owing to the absence of ultra-violet light or to too high a humidity. When a fungus produced an abortive fruit body, which ceased to develop further or formed a hymenium which was becoming overgrown with vegetative mycelium, either the tube, together with the plug *d*, was removed, or if the fruit body was attached to the damp wad *f*, the plug *d* was carefully unwound without disturbing the tube, which was then wedged into position. When the tube is removed it is supported on two Petri dish lids (see Pl. VII, fig. 2), the dish nearer the mouth being filled with water. A thick strip of absorbent cotton wool, saturated with water, was placed on the plug with its ends resting in the dish of water, and a pad of moist cotton wool was placed beneath the fruit body. This dish and pad were never allowed to dry out, since even temporary drying of the fruit body often prevents any further development. The cultures should not be exposed to direct sunlight for at least a couple of days after removal from a dark incubator, and certain fungi, such as *Polyporus Schweinitzii*, should never be exposed to direct sunlight even for a few minutes. Most fungi develop best in strong diffused light, and in this laboratory they are grown on shelves about 8 ft. from a large window, which is open on most days. The amount of ultra-violet light falling on the fungi was probably of the same order as that in moderate shade outdoors.

A more rapid method, which does, however, involve more risk of contamination, is to fill large tubes (30×8 cm. or 20×4 cm. have been used) with the sawdust medium so that the base of the cotton-wool plug comes well into contact with the medium. The mouth of the plug should be wiped free of sawdust before the plug is inserted. Because of the bulk of medium in the larger size of tubes it is advisable to autoclave them at 15 lb. pressure for 1 hr., half an hour being sufficient for the smaller size. The plugs should not project more than 2 cm. beyond the mouth of the tubes and should not fit tightly. In order to reduce the risk of contamination in the larger tubes inoculation of the medium is effected through a small glass tube in the large plug, and this itself has a small separate plug. The large plugs should not be flamed when carrying out inoculations, as the presence of charred cotton may check the growth of the mycelium through the plug. If paper labels are used the gum should contain an antiseptic to prevent moulds developing on them.

After inoculation the tubes should be kept in an incubator in which a moderately high humidity is maintained, by having a dish of water exposed in it. If the plugs are not sufficiently moist for the mycelium to grow freely through them they can be moistened occasionally with a few drops of water, for it is important that the growth of the fungus should not be checked by drying out. After the mycelium has reached the ends of the tubes they are removed from the incubator and placed in the light on

Petri dishes containing water as described above. Pl. VII, fig. 1, shows fruit bodies of *Pleurotus ostreatus* developed by this method.

The most rapid method of obtaining fruit bodies is to remove the plugs entirely when the mycelium has grown about half-way down the tube and then to place a wad of wet absorbent cotton wool in the mouth of the tube just out of contact with the medium; later, when vigorous surface growth is developing, this pad may be gently pushed down, so as to touch the medium. The tubes containing the pads are then placed on Petri dishes containing water, in such a position that the light from the window falls on the open mouths of the tubes. Pl. VII, figs. 3 and 4, shows fruits of *Ganoderma resinaceum* and of *Merulius tremellosus* respectively, developed in this way. The tubes may be tilted slightly so as to facilitate the addition of water to the absorbent pads. When the fruit bodies of agarics begin to develop the tubes are best stood up vertically in baskets and a little water added daily. If the atmosphere of the laboratory is very dry a ring of absorbent wool may be tied around the end of the tube and kept moist.

Certain agarics were found to develop fructifications more readily when the amount of accelerator in the sawdust was increased, and up to 40 % of the total was sometimes used. These fungi also require on the whole rather higher moisture contents, and the medium should initially contain about two and a half times its dry weight of moisture.

It was found that fleshy agarics that normally form long stipes, fruit best in tubes half-filled with the sawdust medium. This enables the pileus to form inside, or just outside, the rim where the atmosphere is relatively moist. When attempts are made to obtain fruits of an unidentified species, a tube half-filled with the sawdust medium is a useful supplement to the other cultures. (Pl. VII, fig. 5, shows a fruit body of *Pholiota adiposa* developed by this method.)

Although contamination with moulds is occasionally troublesome when the plugs are entirely removed, yet when the wood-destroying fungus is growing vigorously, fruit bodies are usually developed before any extensive mould growth becomes evident. Generally speaking, moulds develop on these sawdust cultures only when the fungus has ceased to grow actively.

In the table a list of the fungi tested is given, and it will be noted that in eighty-two out of the ninety-two species tested fructifications were formed. Of the ten species which did not fruit all but one were old isolations.

Conditions necessary for formation of fructification in laboratory

No single standard method can be expected to induce fructification in all species of wood-rotting fungi equally, for they behave very differently under natural conditions. Some form fruit bodies in a few months after the tree or log is infected; others, such as *Trametes Pini*, do not normally fructify until many years after the tree is infected. Some species form their fructifications throughout the year, others only during a limited season, and it is evident that they vary greatly in the amount of light which they require to produce typical sporophores. *Coniophora cerebella* and *Trametes*

List of fungi grown on sawdust medium

The fungi were isolated at the Forest Products Research Laboratory except where the name of the supplier is stated.

Fungus	Time between inoculation and fruiting (if any) weeks
Armillaria mellea (Vahl) Fr. (2 strains)	No fruiting
A. mucida (Schrad.) Fr.	6
Collybia velutipes (Curt.) Fr.	7
Coniophora cerebella Pers.	10
Daldinia concentrica (Bolt.) Ces. & de Not.	No fruiting
Echinodontium tinctorium E. & H. (Mounce, Canada)	8 (Ab.)
Flammula sapinea Fr.	No fruiting
Fomes annosus Fr. (2 strains)	8
F. Clelandii Lloyd (McClennan, Australia)	8½
F. conchatus (Pers.) Fr.	10
F. fomentarius (Linn.) Fr.	7
F. fraxineus (Bull.) Fr.	7½
F. igniarius (Linn.) Fr. (2 strains)	11–12
F. lividus Kalchbr. (Lurie, South Africa)	8½
F. melanoporus Mont. (Bagchee, India)	9
F. pinicola (Sw.) Cke.	10
Ganoderma applanatum (Pers.) Pat.	11
G. oregonense Murr. (Mounce, Canada)	No fruiting
G. resinaceum Boud.	12
Hydnum coralloides (Scop.) Fr.	7
H. erinaceus (Bull.) Fr.	6
Hypholoma sublateritium Schaeff.	31
Irpex obliquus (Schrad.) Fr.	6½
Lentinus cochleatus (Pers.) Fr.	7
L. lepideus Fr.	6
Lenzites betulina (Linn.) Fr.	7½
L. striata Swartz (from imported timber)	5
*L. trabea** Pers. (Richards, U.S.A.)	9
Merulius lacrymans (Wulf.) Fr.	9
M. serpens (Tode) Fr.	10
M. tremellosus (Schrad.) Fr.	7
Mycena galericulata Scop.	No fruiting
Panus torulosus (Pers.) Fr.	8 (Ab.)
*Paxillus panuoides** Fr.	6
Phellinus cryptarum Karst.	5
Pholiota adiposa Fr.	7
P. aegerita (Porta) Fr.	11
P. heteroclita Fr.	7½ (Ab.)
P. lucifera (Lasch) Fr. (Mounce, Canada)	No fruiting
P. mutabilis (Schaeff.) Quél.	10½
P. squarrosa (Müll.) Fr.	7
Pleurotus euosmus (Berk.) Cke.	6
P. lignatilis Fr.	12
P. ostreatus (Jacq.) Fr.	6½
P. palmatus (Bull.) Quél.	8
P. ulmarius Bull.	12 (Ab.)
Polyporus anceps Peck (Davidson, U.S.A.)	10
P. balsameus Peck (Mounce, Canada)	8
P. benzoinus (Wahl.) Fr.	7
P. borealis (Wahl.) Fr. (Mounce, Canada)	8½
P. brumalis (Pers.) Fr.	No fruiting
P. dichrous Fr. (Overholts, U.S.A.)	6½
P. frondosus Fr.	6
P. fumosus (Pers.) Fr.	9
P. giganteus (Pers.) Fr.	8
P. gilvus Schw. (Lurie, South Africa)	11
P. obtusus Berk. (Humphrey, U.S.A.)	7
P. picipes Fr.	12
P. radiatus (Sow.) Fr.	12
P. rugulosus Lév. (Lurie, South Africa)	8
*P. Schweinitzii** Fr. (2 strains)	6–7
P. shoreae Wakefield (Bagchee, India)	13
P. sulphureus (Bull.) Fr.	10
P. Tuckahoe (Güssow) Sac. & Trott (Mounce, Canada)	15 (Ab.)
P. tulipiferus (Schw.) Overholts (Mounce, Canada)	10
Polystictus abietinus (Dicks.) Fr.	6
P. cinnabarinus (Jacq.) Cke. (Cummins, Australia)	8
P. hirsutus (Wulf.) Fr.	4½
P. leoninus Klotz. (Bose, India)	6
P. pergamenus Fr. (Mounce, Canada)	10
P. sanguineus (L.) Mey (Bagchee, India)	8½
P. versicolor (Linn.) Fr. (3 strains)	7
Poria incrassata (B. & C.) Burt (Humphrey, U.S.A.)	No fruiting
P. obducens (Pers.) Fr. (Mounce, Canada)	9
P. Rickii (?) (Davidson, U.S.A.)	7 (Ab.)
P. subacida Peck (Mounce, Canada)	12
P. Vaillantii (DC.) Fr.	3
P. vaporaria (Pers.) Fr.	5
P. xantha Lind.	5
Schizophyllum commune Fr.	5½
Stereum hirsutum Fr.	5
S. illudens Berk. (McClennan, Australia)	7
*S. lobatum** Fr. (McClennan, Australia)	11
S. purpureum Fr.	10
S. rugosum (Pers.) Fr.	10
S. sanguinolentum (Alb. & Schw.) Fr.	6½
S. spadiceum Fr.	12
Trametes heteromorpha (Fr.) Bres. (Mounce, Canada)	No fruiting
T. Pini (Brot.) Fr. (2 strains)	No fruiting
T. rubescens (Alb. & Schw.) Fr.	8
T. serialis Fr. (Mounce, Canada)	5
T. violacea Lloyd (Lurie, South Africa)	9

serialis usually fructify on the underside of pieces of wood in the open. *Polyporus Schweinitzii* and *Fomes annosus* usually form sporophores in shaded positions at the base of trees—the latter sometimes on roots in rabbit burrows. By contrast, others, such as *Polystictus versicolor* and *Lenzites sepiaria*, fruit on posts, etc., exposed to full light, and it is logical to expect their light requirements in the laboratory to differ. It is interesting to note that the five agarics which fruit regularly on malt agar in plugged test-tubes in an incubator in the laboratory are species listed by C. Rea as ones which can fructify out of doors in the winter. These are *Collybia velutipes*, *Coprinus micaceus*, *Pleurotus ostreatus*, *P. palmatus* and *Schizophyllum commune*.

Summing up the conditions necessary for the formation in the laboratory of sporophores of wood-rotting Basidiomycetes, the following desiderata appear to be the more important:

(1) The provision of a generous supply of a rich, well-aerated medium; this can be supplied by sawdust of an easily decayed timber, to which readily available nutrients have been added.

(2) A plentiful supply of moisture in the medium.

(3) An atmosphere of moderately high relative humidity, but not a saturated atmosphere, at the surface of the medium and around the developing sporophores. Failure to obtain normal fructifications in culture vessels is often the result of an excessively high humidity within them.

(4) Exposure to light of moderate intensity, the length of exposure and the intensity of the light depending on the species of fungus and usually bearing a relation to its normal ecological requirements.

Summary

Methods are described for cultivating wood-rotting fungi on a medium consisting of sawdust to which various nutrients are added, so as to produce in fairly short periods fructifications which are sufficiently typical of the species to be readily recognized.

The conditions most favourable for the production of sporophores by wood-rotting fungi in culture are briefly discussed, and it is concluded that they include (1) the provision of a rich medium containing readily available food materials in addition to wood substance, (2) plentiful supply of moisture to the substratum, (3) an atmosphere not saturated, but having a fairly high relative humidity, around the developing fruit bodies, (4) exposure to daylight of moderate intensity.

The work described in this report was undertaken as part of the programme of the Forest Products Research Board and is published by permission of the Department of Scientific and Industrial Research.

Notes on table

Beech sawdust was used throughout, except for those species marked with an asterisk, for which Norway spruce sawdust was used. A number of other species were successfully grown on spruce sawdust as well as on beech dust.

Though in by no means all the species tested were the fructifications normal or identical with those formed in nature, yet they mostly showed the typical features by which they could have been recognized had the identity of the culture been unknown. Only in those species where (Ab.) is placed alongside the number in the time column were the fruit bodies abortive or imperfect.

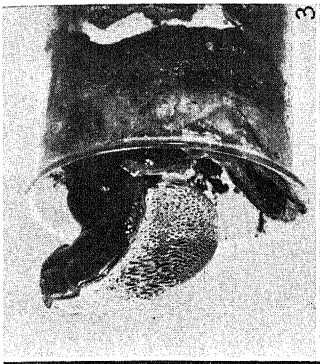
REFERENCE

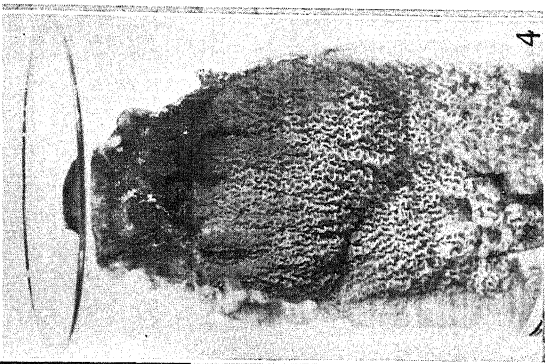
BADCOCK, E. C. (1941). New methods for the cultivation of wood-rotting fungi. *Trans. Brit. myc. Soc.* XXV (2), 200–5.

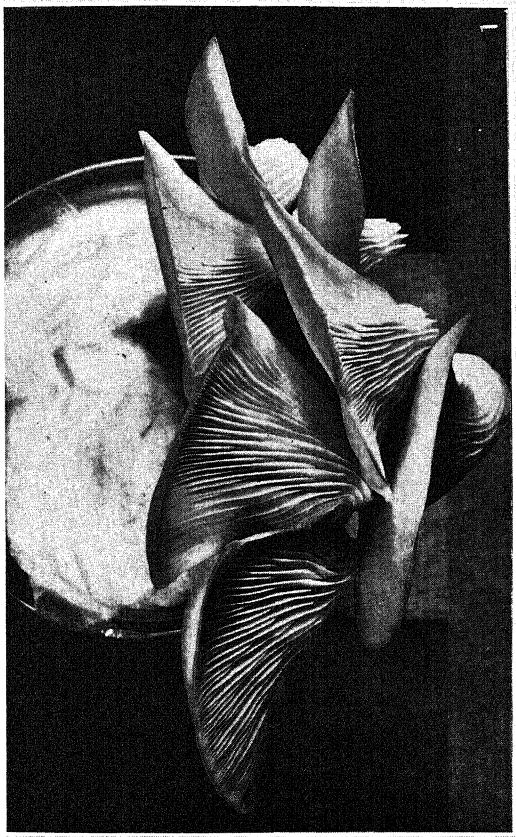
EXPLANATION OF PLATE VII

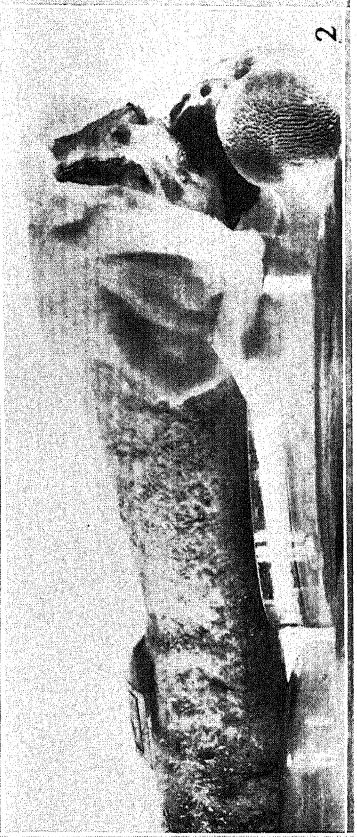
Fig. 1. *Pleurotus ostreatus*—sporophores formed from mycelium which has grown through plug: 8 weeks after inoculation. (× $\frac{2}{3}$.)
Fig. 2. *Fomes Clelandii*—fructification formed after 4 months on plug at end of tube after removal from flask. Note strip of wet cotton wool to keep plug moist. (× $\frac{1}{2}$.)
Fig. 3. *Ganoderma resinaceum*—fructification formed at mouth of tube after removal of plug: 12 weeks after inoculation. (× 1.)
Fig. 4. *Merulius tremellosus*—fructification formed at mouth of tube after removal of plug: 7 weeks after inoculation. (× 1.)
Fig. 5. *Pholiota adiposa*—plug removed and tube only half-filled with medium: 7 weeks after inoculation. (× $\frac{1}{2}$.)

(*Accepted for publication* 30 *September* 1942)


3


4


1


2


5

STACHYBOTRYS

By G. R. BISBY, *Imperial Mycological Institute, Kew*

(With 9 Text-figures)

Historical

The genus *Stachybotrys* was founded by Corda (1837; commonly but erroneously cited as dating from his *Anleitung*, 1842) with one species, *S. atra*. The generic diagnosis, translated, is: 'Fertile hyphae ("stipes") septate, branched; branches crowned at the apices with very short, verticillate, mammillate branchlets forming a capitulum; spores two-celled, homogeneous, regularly placed and within the capitulum.' He added a note that this genus with *Dendryphium*, *Puccinia*, *Dicoccum*, and *Didymosporium* constituted a family Stachybotrydeae. His specific diagnosis is: 'St. atra. Mycelial tufts thin, black; fertile hyphae dichotomous, few-septate, olivaceous-yellow; branchlets white above; spores fuscous, ovate, with a thick transverse septum, 0·000340 Pariser Zolles. On walls, Prague, in winter.' The Paris Zoll is equal to 27·9 mm.; that makes the spores about 9·5 μ long. The branchlets are phialides. Corda's figures are reproduced here (Fig. 1).

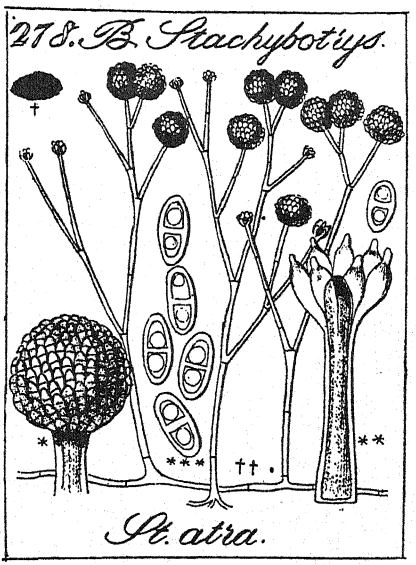


Fig. 1. Corda's figures, 1837. The fungus is shown natural size at †.

Berkeley (1841) described and figured *Sporocybe** *lobulata*, noting that it 'appears to have a great resemblance to *Stachybotrys atra* Corda, but the lobes are not so distinct; neither are they mammillate, and the sporidia have no true septum'. Later, Berkeley and Broome (1859) recorded *S. atra*, remarked that its spores 'are not in any stage echinulate, nor are they so broad' as those of *Sporocybe lobulata*, 'which evidently belongs to the same genus', and the next year Berkeley (1860) placed the latter under *Stachybotrys*.

In the meantime Bonorden (1851) had described and figured *S. alternans* (Oudemans later drew the better-known but rather schematic illustration). Then Saccardo and Cooke each added a couple of species of doubtful status. Grove (1886) described *S. dichroa* with spores stated to be one-

* *Sporocybe* sensu Berkeley did not have synnemata.

septate but figured as biguttulate. A description sent to Saccardo appeared in *Sylloge* IV before Grove's own publication.

Thus *Stachybotrys* in 1886 had eight so-called species, six of which had one-celled spores and two (including what is now known as the type) were said to have two-celled spores. Saccardo compiled the genus in the Dematiaceae-Amerosporae, and added '(spurie?)' before each mention of '1-septatis'. The dozen specific names added since 1886 have all applied to specimens with one-celled spores. Saccardo had fixed the generic concept: not from any 'type species' but from all the species he knew. He did not know, nor do we know, a genus with one-septate spores but in other ways like the fungus that had come to be known as *Stachybotrys*, a name still universally used for a common fungus on old plant material including damp paper, cotton, and linen; it may cause commercial damage (see Sée, 1919; Thaysen & Banker, 1927; G. Smith, 1938).

Von Höhnel (1923), in some notes published posthumously, argued that *Stachybotrys* Corda referred to a fungus which grew on walls, had two-celled spores, and had never been found again; that *Stachybotrys* of subsequent authors grew especially on paper, had one-celled spores, and must be renamed. He guessed that the name *Memnonium* Corda could be used, reported that the type of *Synsporium* Preuss was a species of what had been called *Stachybotrys* but must now be called *Memnonium*, and gave the following synonymy:

Memnonium effusum Corda, 1837

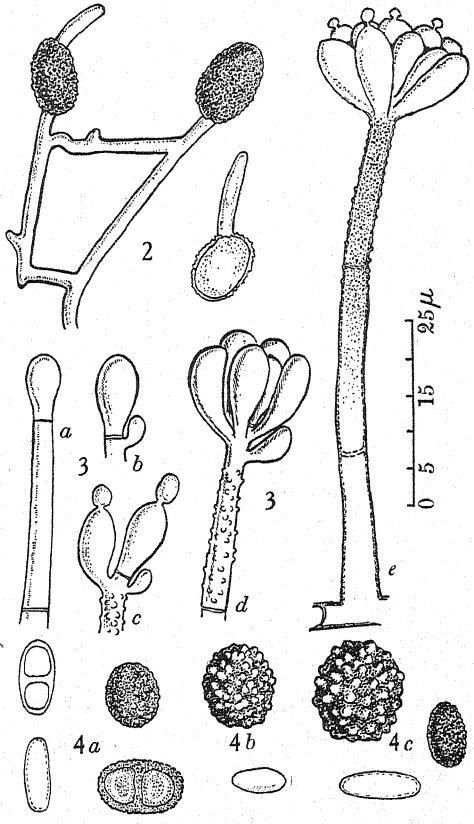
Synsporium biguttatum Preuss, *Aspergillus alternatus* Berk., *Sporocybe Desmazieri* Corda, *Sporocybe lobulata* Berk., *Stachybotrys alternans* Bon., *Memnonium sphaerospermum* Fuckel.

This is a curious mixture of sense and nonsense. Corda's figure and description of *Memnonium effusum* might refer to many a fungus, but there is no indication that it had the distinctive phialophores and phialides which Corda figured the same year for his *Stachybotrys*. There is no type material, and Saccardo's guess that *Memnonium* was a *Trichosporium* might better stand. Corda's figures of *Sporocybe Desmazieri* do not look much like *Stachybotrys*. How did von Höhnel know that there was no paper (or other cellulose) on the wall from which *S. atra* came, or that the spores were really two-celled? He did not examine the type specimen, which was later reported (Pilat, 1938) to be in Prague. Until such examination may be possible, it seems much more reasonable to assume that Corda's specimen has non-septate spores, for (see below) many fresh, biguttate spores appear septate.

Observations on cultures, specimens, and nomenclature

A score of specific names has been applied to *Stachybotrys*, but only three—*S. atra*, *S. lobulata*, and *S. alternans*—are commonly reported. Of these three, type material of *S. lobulata* only is available to me at the moment, but type specimens of a half dozen other 'species' have been examined. First, however, a few terms need mention, then cultures such as may readily be obtained will be described.

The conidiophore is a compound structure in *Stachybotrys*, for which these terms are here used (see Figs. 3, 5): *phialides*, the structures which produce the conidia; *phialophore*, the 'simple conidiophore' distinctive of the genus, with its crown of phialides at the apex; *compound phialophore*, the 'branched conidiophore' which consists of the primary phialophore and one or more secondary phialophores arising as branches. For mycelial aggregations these terms are used: *strands*, decumbent groups of parallel or intertwined hyphae; *ropes*, erect, conspicuous hyphal structures which may simulate synnemata or coremia on rich media such as malt agar, being up to 5–10 mm. high and 1 mm. wide at the base, tapering upward. These ropes of hyphae generally occur in groups. The term 'synnema' is not used here because that suggests the Stilbaceae; *Stachybotrys* belongs to the Dematiaceae.



Figs. 2–4. *Stachybotrys atra*. 2, germinating spores and formation of hyphal anastomoses. 3, stages in development of phialides: the simple phialophore 3*e* is indicated in optical cross-section. 4*a*, spores, young and old, of the Nottingham isolation, showing range and guttae. 4*b*, two spores showing range in the culture Timonin 1803. 4*c*, three spores showing range in the type specimen of *S. scabra* Cooke & Harkn. All × 1000.

Culture 1. Isolated late in 1941 from rotting canvas, Nottingham, and sent to Miss E. M. Wakefield. —A spore germinates by one or two germ tubes which break through the spore wall, generally near one or both ends (Fig. 2). The young hyphae anastomose and form a hyaline mycelium which grows about 1 mm. in radius each day at room temperature. Strands are formed on the surface of the medium. Within a week conidiophores and conidia develop and turn dark, giving to spore-producing areas a dull, inky-black appearance, often with glistening droplets of slime. In older cultures the vegetative hyphae may show a tinge of olivaceous.

A primary phialophore rises from a hypha—a simple hypha or one in a strand or a rope. The apex swells, then becomes cut off by a septum to form the first phialide; meanwhile one or two septa develop along the phialophore (Fig. 3; Zopf, 1890, gives good figures). The first phialide produces an apical bud which grows into a conidium, while four or five

more phialides form successively in a circle below the first; only the apical phialide seems to be cut off by a septum. Meanwhile the phialophore becomes roughened, and soon the phialides also. The conidia turn dark while still immature, and the apex of the phialophore also becomes olivaceous as the spores develop. Then another circle of four or five phialides may form in succession below the first whorl, making a compact crown surmounting the phialophore. Each phialide produces conidia (slime spores) in succession until a head of fifty or more collects, held in a cluster by slime. Frequently two or more clusters combine.—A mature phialophore is olive brown, especially above, about 5 μ wide at the base and 3 μ at the apex, of varying length, commonly 50–100 μ. A secondary phialophore frequently develops as a branch from the primary, and so on, forming a compound phialophore (Fig. 5) with more or less definite alternate branching.

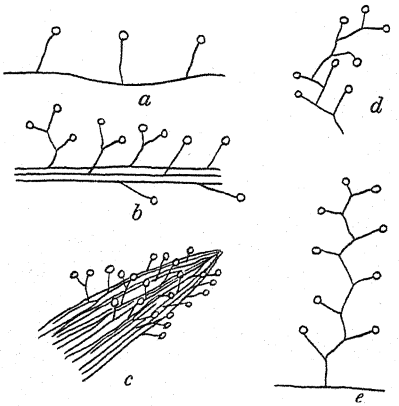


Fig. 5. Diagrams of arrangement of phialophores of *Stachybotrys atra*: *a*, simple or primary phialidophores arising from a hypha; *b*, simple and compound phialophores from a strand and *c*, from a rope; *d*, *e*, the usual alternate arrangement of phialophores.

The phialides are 10–15 × 5–7 μ, obovate or pyriform, becoming roughened and olivaceous. Corda's description of them as 'mammillate' refers to the young spores at the apices. A mature phialide in water may put out a hypha. The phialides are not deciduous, but eventually collapse *in situ*. Phialides are generally (and by definition) flask- or ninepin-shaped cells, cut off by septa. It seems to us, however, that the term phialide should be used for the spore-producing organs of *Stachybotrys*, despite their shape and the lack of distinct septa except beneath the terminal phialides.

The conidia (Fig. 4*a*) first abstricted are 8–11 × 3·5–6 μ, smooth or nearly so, translucent olive brown. In older cultures many of the spores are conspicuously roughened; wider (8–12 × 5–7·5 μ; some are subglobose), and many are opaque and black. The translucent spores, in young or old cultures, show none, one, three or, most commonly, two guttulae; the latter are often so placed as to lead an observer to think the spores two-celled until he makes appropriate tests, which show that they are non-septate. Under Corda's microscope, such spores would seem definitely septate.

Several single-spore cultures were made, but there was no obvious difference, macroscopic or microscopic, between them. When these cultures were about a month old, most of them (and less commonly mass transfers) showed a pale, more or less spreading, hyphal overgrowth which suggested a contaminant or a parasite. Transfers from this overgrowth demonstrated that it belonged to the *Stachybotrys*; successive transfers from

it soon produced colonies nearly or quite sterile, some with a salmon-pink colour, others nearly white. This is another example of the dual phenomenon (Hansen, 1938; see also Presley, 1941), and explains why the fungus may seem to 'run-out' if transferred from older cultures bearing overgrowth.

Culture 2. An isolation from soil, Canada (M. Timonin No. 1803), differed only in having some spores even narrower in young cultures, where they were 8–10 × 3–5 μ, but even wider (8–11 × 5–10 μ, many globose, rough, and opaque) in cultures a month old (Fig. 4*b*).

Culture 3. Another soil culture (isolated 1939, G. Smith No. 158) differed from the Nottingham fungus in having earlier and more pronounced darkening of the phialophores and phialides.

Four other isolations were studied, but all fell within the range shown by the three mentioned above. The seven cultures evidently belonged to one and the same species.

What name should be applied to this common and widespread species? Examination of the type specimen shows that it can be called *Stachybotrys lobulata* (Berk.) Berk., a name we have commonly used in the past. However, since Corda's figures and description make it almost certain that his species was the same, *S. atra* Corda is used here to obviate the future necessity of changing to his name when and if his type is re-examined. In the very unlikely chance that his type proves to be different, then *Stachybotrys* obviously should become a *nomen conservandum propositum* in the sense now universally accepted.

As noted above, Berkeley recorded *Stachybotrys atra* in 1859. The specimen he examined is marked by him 'Sporocybe lobulata with Stachyb. atra Batheaston March 1859'. It is evident from a glance at this specimen and from Berkeley's remarks quoted above that he considered the young stage of *Stachybotrys* to be *S. atra*, the older to be *S. lobulata*. There would still be ample justification for two or more specific names were it not that single-spore cultures prove that there is variability, especially between spores in young and in old cultures. The 'fathers of mycology' cannot be blamed for basing names on what seemed to them good specific characters.

The first specific epithet after Corda's which applies to the common *Stachybotrys* appears to be that of *Aspergillus alternatus* Berk. (1838). Berkeley transferred it to *Sporocybe* in 1841 and reported that it was nearly allied to *S. lobulata*. Apparently no one has transferred *S. alternata* to *Stachybotrys* (Saccardo made it a *Periconia*). As von Höhnel (1923) reported, the type specimen is the same species as *S. lobulata*, herein considered *S. atra*.

There is no feature of the original description or figure of *Stachybotrys alternans* Bon., which constitutes a basis for a distinct species. Both *S. scabra* Cooke and Harkness (Fig. 4*c*) and *S. verrucosa* Cooke and Massee are well developed *S. atra*; the type (and only) specimen of each in Kew Herb. has ellipsoid, smooth, pale young spores 4 μ wide as well as very rough, opaque, subglobose spores up to 14 × 12 μ. *S. asperula* Massee, correctly redescribed by Petch (1931) (his 'catenulate' means that the spores arise successively from phialides. They are not in chains), is also mature *S. atra*. The

paper substratum came from Ceylon, but there is no assurance that the fungus did.

Pending study of the type specimens by future workers, we may gather from the descriptions or figures that the following were probably *Stachybotrys atra*: *S. atrogrisea* Ell. and Everh. (the authors stated that it might be a 'variety' of *S. atra*), *S. gracilis* Ém. March., *S. elasticae* Koord. and *S. dakotense* Sacc. The following are possibly *S. atra*: *S. pulchra* Speg., *S. cylindrospora* Jensen, and *S. Voglinii* Cif.

Species belonging to the so-called subgenus *Sterigmatobotrys* (which was first proposed by Oudemans in 1886 as a genus), viz. *Stachybotrys elata* Sacc., *S. papyrogena* (Sacc.) Sacc., and *S. socia* (Sacc.) Sacc., apparently do not belong in the genus *Stachybotrys*, but I have seen no authentic or other specimens. Costantin in 1888 proposed the genus *Phragmostachys*, said to be based on '*P. atra*', but his figures show that 'atra' is a lapsus calami for 'elata'; *Phragmostachys* is a synonym of *Sterigmatobotrys*.

The diagnosis and figures of *Stachybotrys elongata* Peck indicate that the fungus is not a true *Stachybotrys*.

Cooke (1883) described '*Stachybotrys sub-simplex*, *Cooke*, *Rav. Amer. Fungi*, No. 775. Effusum, atrum. Hyphis simplicibus, erectis, tenuibus, septatis, superne lobato-capitatis. Sporis globosis, laevibus, atrofuscis (·006 mm. diam.). On *Musa* (Rav., 3368). Darien, Georgia.'

This species has heretofore been reported from the one collection only.* The type specimen is marked by Ravenel '3368 on leaves of banana (Musa) Darien Ga. Nov. '81 H.W.R.' Cooke's copy of Ravenel *Fungi Americani Exsiccati* 775 is marked in ink '3368'. There is a good development of an effuse, sooty-black mould. The septate hyphae are pale brownish, 2–4 μ wide. The phialophores are somewhat roughened, 4–6 μ wide, up to 200 μ or more long, darker than the hyphae, simple (so far as noted, i.e. arising from the hyphae, not from other phialophores), crowned above by five to ten pyriform or ellipsoid phialides 10–12 × 4–6 μ. Conidia globose or subglobose, five to nine (mostly six to eight) μ, formed in clusters on the phialides (Fig. 6).

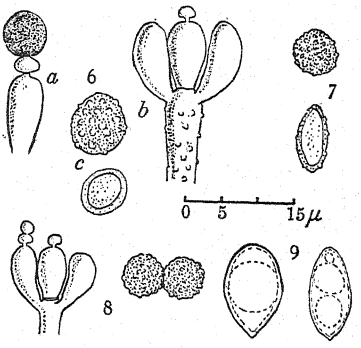
On the same herbarium sheet in Kew Herb. is affixed a Californian specimen '2229 On Agave. Harkness' to which Cooke has added sketches of roundish, dark spores and a note: '*Stachybotrys* (?) too sandy to examine properly'. The rough surface of the leaf and the black fungus are coated with very fine sand grains. After a little manipulation, phialophores of *Stachybotrys* were revealed; these were 3–4 μ wide, somewhat roughened, pale with a tinge of olive, bearing a crown of phialides 10–12 × 5 μ, with conidia globose to oval, 4–6 (7) × 3–4 μ.

To supplement these two dried specimens, we received in 1937 cultures (since lost) and slides of a *Stachybotrys* isolated by Dr G. R. Bates from citrus fruit washings, Southern Rhodesia. The colonies were hyaline, then dull greenish black from the conidial masses. Hyphae hyaline, 2 μ (or less) wide, often aggregated into strands; phialophores typically simple, erect, one to three septate, inconspicuously roughened, 40–50 μ long, 3–5 μ wide

* Fig. 172 in Wardlaw's *Diseases of the Banana*, 1935, is of *S. subsimplex*, though by accident labelled *Haplographium*.

and hyaline at the base, becoming pale fuscous above, about 2 μ wide at the apex which bears up to ten obovate phialides which are 6–10 × 3–4 μ, straight or curved, hyaline becoming brownish; conidia formed in clusters, variable, globose and 3–6 μ or oval and 4–10 × 3–4 μ, becoming opaque black and somewhat roughened (Fig. 7).

This fungus in culture showed variability comparable with that of *Stachybotrys atra*, but the phialophores were generally simple, the spores smaller and often globose even in young cultures. Pending further collections, we are using the name *S. subsimplex* for the two herbarium specimens and Bates's cultures.



Figs. 6–9. 6, From the type specimen of *Stachybotrys subsimplex*: *a*, phialide with one young spore and one nearly mature; *b*, young phialophore bearing three young phialides; *c*, mature spore in surface view and young spore in optical section. 7, Two spores from Bates 239, considered to be *S. subsimplex*. The phialides are like those shown in Fig. 6. 8, Tip of young phialophore and two spores from *Memnoniella echinata* (Riv.) Galloway. 9, Two spores of the 'pink *Stachybotrys*' from Canada. All × 1000.

We now mention *Gliobotrys*, founded by von Höhnel (1902) for fungi like *Stachybotrys* except in having hyaline fertile hyphae [phialophores]. The type species, *Gliobotrys alboviridis* on decayed wood, was described with conidia 4–6 × 3–4·5 μ. It seems possible that the fungus was *Stachybotrys subsimplex* as here interpreted.

As a second species of *Gliobotrys*, von Höhnel transferred *Stachybotrys dichroa* Grove because its conidiophores were said to be hyaline. An examination of a bit of Grove's type shows, however, that it is young *S. atra*; some of the phialophores have a tinge of olivaceous. In any event, two distinct genera are not needed for Dematiaceae alike except that one has hyaline phialophores which become dark, the other phialophores which are supposed to remain hyaline.

Late in 1937 we received from Dr J. E. Machacek (his No. 408) a fungus isolated from soil, Winnipeg, which is more than a *Gliobotrys*; it is definitely one of the Moniliaceae, being salmon pink on most media. No dark tinge has ever been seen in any part of the fungus. It grows vigorously (a culture fifty-one months old promptly revived when melted agar was added) and produces masses of slime-spores 10–12 (13) × 5–8 μ on phialides on roughened phialophores. In other words, the fungus is like *Stachybotrys* except in colour; indeed, it is like *S. atra* except in colour, in its slightly longer (12–17 μ) phialides, little branching of phialophores, and in its spores which are somewhat pointed at one or both ends (lemon-shaped to broadly fusiform, fig. 9), generally with only one large guttule, and remaining smooth or nearly so.

At first thought it seems obvious that this fungus requires a genus in the Moniliaceae since, in Saccardo's classification, colour determines the family. Since no genus seems to fit, a new one is indicated, unless one begs the question by 'emending' *Gliobotrys* out of the Dematiaceae.

Upon second thought, it seems strange that no one has ever reported such a fungus, for most soil moulds are widely distributed. It came from the centre of North America, not from unknown Tibet. How much of this fungus is known 'in nature'? The progeny of one spore only is known to us, a spore isolated by dilution plates from soil that is exposed to frigid winter and the heat and ultra-violet rays of summer; a spore that had to submit further to several laboratory manipulations before it developed its first bizarre, pink colony. No; there are already too many genera based on freaks. Furthermore, we managed to isolate from typical *Stachybotrys atra* a mycelioid growth of the identical pink colour. In view of the differences noted above, and of failure to get fusions between germ tubes from *S. atra* and from the pink fungus, we cannot call the latter 'pink *S. atra*'; but we propose to call it 'pink *Stachybotrys*' until there is more evidence that Nature has definitely added such a fungus to her flora.

Memnoniella von Höhnel (1923) requires a word. It was described as differing from *Stachybotrys* (as '*Memnonium*') in having catenulate spores. Galloway (1933) obtained a fungus which was found to agree with von Höhnel's type specimen; like the type, it came from cotton yarn. Since an earlier figure and description by Rivolta seemed to refer to the same fungus, the combination *Memnoniella echinata* (Rivolta) Galloway was made.

Galloway's isolation, which has now been ten years in culture, was obtained from the Lister Institute. There is little to add to Galloway's description. The mycelium is salmon-pink like that of the overgrowth of *Stachybotrys atra* mentioned above and, on rich media, produces strands and numerous small, erect ropes of hyphae. Spore production is now somewhat reduced; phialophores unbranched, conidia rough-globose, 4–5 μ, in chains which readily break up, sometimes forming clusters (Fig. 8).

Memnoniella is a suspiciously rare fungus, with two definite records and one probable, all from Europe (though the two on cotton yarn may, of course, have been introduced with the cotton). We can add another; we have a slide made from a culture isolated by G. R. Bates, Southern Rhodesia, with spores somewhat disk-shaped, 4·5–5·5 × 3–4 μ in the chains, i.e., in side view, and 4·5–5·5 μ when flat. The chains are rather persistent.

We suggest the possibility that *Memnoniella echinata* may be *Stachybotrys subsimplex* with slime production reduced sufficiently to allow the retention of spores in chains. Galloway's fungus was a single colony from 'cotton yarn, heavily mildewed with *Stachybotrys* sp., and kept for some years in a sealed jar'; Bates's isolation was from the citrus washings which produced several cultures we called *S. subsimplex* above. Several fungi, including *Gliomastix* (which has similarities with *Stachybotrys*, see Mason, 1941) and *Trichoderma* (Bisby, 1939), may produce spores in heads or in chains, depending on conditions.

Summary of taxonomy and nomenclature of *Stachybotrys* Corda, 1837

Hyphae, phialophores, and phialides hyaline, brightly coloured, or dark; strands or ropes of hyphae may be produced. Conidia (slime-spores) one-celled, normally dark and accumulating into a cluster. The distinctive

characteristic of the genus is the septate phialophore or simple conidiophore bearing a crown of phialides and generally becoming dark. A phialophore arises directly from a hypha or, frequently, from another phialophore. Perfect stage unknown.

Synonyms: *Synsporium* Preuss, 1851, fide von Höhnel.
?*Gliobotrys* von Höhnel, 1902.

The two species recognized by the writer and described in some detail above are summarized here:

(1) *Stachybotrys atra* Corda, 1837

Synonymy, excluding nomenclatural synonyms: *Aspergillus alternatus* Berk., 1838; *Sporocybe lobulata* Berk., 1841; *Stachybotrys alternans* Bon., 1851 (presumably); *Synsporium biguttatum* Preuss, 1849 and 1851, fide von Höhnel; *Memnonium sphaerospermum* Fuckel, 1869, fide von Höhnel; *Stachybotrys scabra* Cooke & Harkness, 1884; *S. dichroa* Grove, 1886; *S. asperula* Massee, 1887; *S. verrucosa* Cooke & Massee, 1888; ?*S. atrogrisea* Ellis & Everh., 1888 (type not seen); ?*S. gracilis* Ém. Marchal, 1894 (type not seen); ?*S. elasticae* Koord., 1907 (type not seen); ?*S. dakotense* Sacc., 1917 (type not seen); *S. pulchra* Speg., *S. cylindrospora* Jensen and *S. Voglinii* Cif. are possible synonyms.

Each phialophore may produce another as a branch; phialides 10–16 × 5–7 μ; conidia 8–12 (14) × 4–9 (12) μ, elliptical to oval on younger growth of the fungus, often subglobose on older growth.

(2) *Stachybotrys subsimplex* Cooke, 1883, tentatively emended. *Gliobotrys alboviridis* von Höhnel, 1902, may be a synonym; *Memnoniella echinata* (Rivolta) Galloway, 1933, is similar except in having catenulate spores.

Phialophores generally simple; phialides 6–12 × 4–6 μ; conidia globose, 3–9 μ or elliptical, 4–10 × 3–5 μ.

Doubtful species: *Stachybotrys crassa* Él. March., 1895. Conidia globose, 16–18 μ. One collection on dung, Belgium. Marchal's figure of a phialophore indicates that he had a *Stachybotrys*, but until the type specimen can be examined, or the species rediscovered, *S. crassa* must remain somewhat doubtful.

Excluded species: *Stachybotrys elata* Sacc., *S. papyrogena* (Sacc.) Sacc., *S. socia* (Sacc.) Sacc., *S. elongata* Peck.—Von Höhnel (1912) suggested that the following might belong to *Stachybotrys*: *Periconia amphispora* (Bon.) Sacc., *P. digitata* (Cooke) Sacc. and *P. minima* (Cooke) Sacc. The type of *P. minima* is not a *Stachybotrys*. No specimen of *P. digitata* has ever been placed in Kew Herbarium. No material of *P. amphispora* has been seen by me.

Discussion

This paper is intended as a small contribution toward the large amount of synthesis still to be undertaken in the taxonomy of fungi. No matter how much a 'splitter of species' one may be by inclination, he cannot ignore the variability manifest in cultures started from a single spore. We have

not ascertained how or why the spores in a young culture of *Stachybotrys atra* are elliptical, translucent, and nearly smooth, whereas many of those in an older culture are rounded, opaque, and rough; but we are sure of the fact, and that the same sequence occurs in the field. Not only do the spores vary, but also the hyphae, phialophores, and phialides. Two or three early names were proposed, rightly for those days, on such variants; a dozen other names have merely accumulated during a century of emphasis on analysis in the taxonomy of fungi. *S. atra* is the only common species in north temperate regions; it has eight specific names still recognized in British literature: six under *Stachybotrys*, *Aspergillus alternatus*, and *Synsporium biguttatum* (Dale, 1914). Certain other countries have even more names for the fungus.

Stachybotrys subsimplex is here interpreted as the second good species of the genus. It is a saprophyte apparently of warmer regions. It is suggested that possibly both *Gliobotrys* and *Memnoniella* were based on this species or variants of it: whatever their status their apparent rarity casts suspicion upon them.

In current taxonomic literature there are thousands of specific and hundreds of generic names which only confuse; some of them were certainly based on mere freaks, and many on hasty or careless work. One may propose, as in this paper, to reduce a few names to synonymy; but there is no way to eliminate a name, once published. Generic names are particularly in need of synthesis and rationalization; more than seven thousand have been proposed for fungi.

The writer, being an old offender, is in a position to remark that local lists of fungi, though often useful, provide human temptation to add 'new records'. I recorded *Stachybotrys* '*cylindrospora*' and '*S. lobulata*' from Manitoba; but the brief notes added make it clear that one was young, the other old, *S. atra*. Similarly, the second record of *S. dichroa*, published by Crossland, refers to a specimen marked *S.* '*dichroa* Grove plus a few other things. On dead stem of *Epilobium*.' There is no *Stachybotrys* evident under a lens, but Crossland's coloured drawing indicates that there had been a bit of pale, young *S. atra*.—It must be said, however, that both Crossland and I had to rely on analyses, for there was no synthesis of the genus *Stachybotrys*.

Summary

1. *Stachybotrys*, with twenty specific names in current literature, is considered to have two distinct species. *S. atra* is a common mould in north temperate regions, and probably elsewhere. *S. subsimplex* is not well known; we have seen two dried specimens and two or three cultures, all from rather warm areas, which we interpret as belonging to it.

2. *S. atra*, and evidently *S. subsimplex* also, are variable in culture and in the field.

3. *Gliobotrys* has no good distinguishing character. It is suggested that *Memnoniella* and a 'pink *Stachybotrys*' may be unusual or abnormal developments of *Stachybotrys*.

4. A plea is made for synthesis in mycological taxonomy.

Grateful acknowledgment is made to E. W. Mason and other workers at the Imperial Mycological Institute, to Geo. Smith, to Miss Wakefield and the authorities at the Royal Botanic Gardens, Kew, for suggestions and cultures, and the privilege of examining type specimens. Transfers of the '*pink Stachybotrys*' and the Nottingham isolation of *S. atra* have been sent to the National Collection of Type Cultures.

REFERENCES

BERKELEY, M. J. (1838). Notices of British fungi. *Ann. Mag. Nat. Hist.* (1), I, 262 (no. 126).

BERKELEY, M. J. (1841). Notices of British fungi. *Ann. Mag. Nat. Hist.* (1), VI, 434 (nos. 227–8).

BERKELEY, M. J. (1860). *Outlines of British fungology.*

BERKELEY, M. J. & BROOME, C. E. (1859). Notices of British fungi. *Ann. Mag. Nat. Hist.* (3), III, 360 (no. 817).

BISBY, G. R. (1939). *Trichoderma viride* Pers. ex Fr., and notes on *Hypocrea*. *Trans. Brit. myc. Soc.* XXIII, 149–68.

BONORDEN, H. F. (1851). *Handbuch der allgemeinen Mykologie.*

COOKE, M. C. (1883). New American fungi. *Grevillea*, XII, 33.

CORDA, A. C. I. (1837). *Icones Fungorum hucusque cognitorum*, I, p. 21, f. 278 B.

DALE, E. (1914). On the Fungi of the soil. *Ann. myc., Berl.*, XII, 46, figs. 75–9.

GALLOWAY, L. D. (1933). Note on an unusual mould fungus. *Trans. Brit. myc. Soc.* XVIII, 163–6.

GROVE, W. B. (1886). New or noteworthy fungi. III. *J. Bot., Lond.*, XXIV, 201.

HANSEN, H. N. (1938). The dual phenomenon in imperfect fungi. *Mycologia*, XXX, 442–55.

HÖHNEL, F. v. (1902). Fragmente zur Mykologie. I. *Sitzb. Akad. Wiss. Wien*, Math.-nat. Kl., Abt. I, CXI, 1048–9.

HÖHNEL, F. v. (1912). Fragmente zur Mykologie, no. 789. *Sitzb. Akad. Wiss. Wien*, Math.-nat. Kl., Abt. I, CXXI, 74.

HÖHNEL, F. v. (1923). Studien über Hyphomyzeten. *Centralbl. Bakt.* (2), LX, 1–26.

MASON, E. W. (1941). Annotated account of fungi received at the Imperial Mycological Institute. List II, Fasc. 3, 117–20.

PETCH, T. (1931). Revisions of Ceylon fungi. Part IX. *Trans. Brit. myc. Soc.* XV, 249.

PILAT, A. (1938). Liste der von A. C. J. Corda beschrieben Pilzarten [etc.]. *Acta Mus. Nat. Pragae*, I B, 139–70.

PRESLEY, J. T. (1941). Saltants from a monosporic culture of *Verticillium albo-atrum*. *Phytopathology*, XXXI, 1135–9.

SÉE, PIERRE (1919). *Les maladies du papier piqué.* Thesis, Paris.

SMITH, G. (1938). *An Introduction to Industrial Mycology.*

THAYSEN, A. C. & BANKER, H. J. (1927). *The Microbiology of Cellulose, Hemicelluloses, Pectin and Gums.*

ZOPF, W. (1890). *Die Pilze.*

(*Accepted for publication* 10 *October* 1942)

AN ABNORMAL GROWTH ON MUSHROOMS

By W. A. R. DILLON WESTON and R. ERIC TAYLOR

(With 1 Text-figure)

A bed of mushrooms was grown by one of us on the concrete floor of a disused garage. The bed was prepared, cased and spawned in the orthodox way, with the exception that the depth of compost was rather shallow so that on various occasions it was necessary to apply water. There was relative freedom from fungal and insect pests, but slugs frequently invaded

Fig. 1.

the bed. Excellent yields were obtained and no abnormalities of growth were noted with the exception of one fructification (Fig. 1). A slight corrugation was noted on the pileus of this when it was about the size of a chestnut, and this developed into a knob-like intumescence which, a fortnight later, had attained the dimensions shown in the illustration. The

peculiar folds and convolutions of this knob-like excrescence, resembling somewhat a rose-comb found in some breeds of poultry, consisted of a hymenium bearing basidia and basidiospores. The gills on the under-surface were normal. It was thought that this abnormal condition might have been caused by some slight mechanical irritation to the skin of the pileus, but attempts to reproduce the condition by scratching the surface of a number of caps with a sterilized needle failed. Reference to the literature showed that a similar condition had been described by Lambert (1930), and referred to by Messrs Darlington and Sons, Ltd. (1934) and Brockhuizen (1937), the term applied to it being the 'rose-comb' disease. Lambert (1930) correlated the incidence of this disease with the use of some form of mineral oil in the mushroom houses, and Brockhuizen (1937) induced it by the use of oilstoves or by the fumes of coal-tar creosote. These mushrooms were grown in a garage where oil had been stored, a condition which (according to the above writers) might be conducive to the disease. Berkeley (1836) described 'a most extraordinary and beautiful state of *Agaricus campestris*', and referred later (1860) to a somewhat similar condition observed in several species of *Agaricus* in which 'an hymenium is produced on top of the pileus as well as beneath...'. Teratological specimens of *Collybia* spp. have been described by Buller (1924) and Ramsbottom (1933) and of *Coprinus ephemerus* by Keyworth (1942), and the nature of these appears to be somewhat similar to that described in the present specimen. We are indebted to Mrs W. A. R. Dillon Weston for bringing this specimen to our notice.

REFERENCES

BERKELEY, M. J. (1836). *English Flora* of J. E. Smith, v, ii, 107.

BERKELEY, M. J. (1860). *Outlines of British fungology*, p. 56.

BROCKHUIZEN, S. (1937). [Diseases and Pests of Cultivated Mushrooms.] *Tijdschr. PlZiekt.* XLIV, 3, 113–40. Cited in *Rev. appl. Myc.* XVII, 791.

BULLER, A. H. R. (1924). *Researches on Fungi*, III, 465–71.

DARLINGTON, Messrs W. and Sons, Ltd. (1934). Mushroom diseases. Successive stages in mushroom cultures. Pt. 3. *Mushroom News*, I, 9, 4–11. Cited in *Rev. appl. Myc.* XIV, 345.

KEYWORTH, W. G. (1942). The occurrence in artificial culture of Tremelloid outgrowths on pilei of *Coprinus ephemerus*. *Trans. Brit. myc. Soc.* XXV, 307–10.

LAMBERT, E. B. (1930). Two new diseases of cultivated mushrooms. *Phytopathology*, XX, 917.

RAMSBOTTOM, J. (1933). *Tremella mycetophila* Peck. *Trans. Brit. myc. Soc.* XVIII, 253–6.

(*Accepted for publication* 19 *October* 1942)

NOTE ON THE OCCURRENCE OF *OPHIOBOLUS GRAMINIS* SACC. VAR. *AVENAE* E. M. TURNER IN SCOTLAND IN 1942

By S. D. GARRETT, *Rothamsted Experimental Station, Harpenden*, and R. W. G. DENNIS, *Seed Testing, Plant Registration and Plant Pathology Station, Corstorphine, Edinburgh*

The occurrence of *Ophiobolus graminis* Sacc. var. *Avenae* E. M. Turner in the Tweedside area of Scotland has already been reported by Dennis and Foister (1942). During the past season, we were able to search more extensively for this fungus, which we found to be widely distributed in the counties of Ayr, Kincardine and Aberdeen; we also found the disease in the counties of Fife and Banff. We did not find the disease either in the Lothians or Tweedside, the area from which it was first reported by Dennis and Foister (1942), but crops in these districts were not examined until too late for easy detection of Whiteheads. No search was made in areas other than those listed above.

Measurements were made of the length of fifty ascospores from each of twenty-one collections of diseased material obtained on this survey, viz. eleven from Ayr, five from Aberdeen, four from Kincardine, and one from Fife; the fifty ascospores were selected at random from groups of perithecia taken from several stem-bases in each collection. The data substantiate Turner's (1940) claim that *O. graminis* var. *Avenae* can be distinguished from *O. graminis* proper by difference in mean ascospore length. Whereas mean ascospore length in *O. graminis* proper rarely varies outside the range 70–90 μ, the means recorded by Turner for *O. graminis* var. *Avenae* on field material ranged from 101 to 117 μ. So far, no further data on ascospore length in *O. graminis* var. *Avenae* have been reported; all the original measurements recorded by Turner were made on material collected in North and Central Wales, so that our measurements made on the Scottish collections are deemed of sufficient value for publication (Table 1).

Mean ascospore length in the different collections varied from 96 to 119 μ, a range which exceeds only slightly that reported by Turner (101–117 μ). Modal length varied from 95 to 116 μ; in twelve out of twenty-one collections, modal length of the fifty-spore samples was identical, viz. 105 μ. These data thus support Turner's separation of *O. graminis* var. *Avenae* from *O. graminis* proper, on the basis of differences in ascospore length as well as in host range.

The first authenticated reports of the occurrence of *O. graminis* var. *Avenae* outside Wales were made in 1940 by Mr N. C. Preston, from Sidbury in Shropshire, and by Dr F. T. Bennett, from Threlkeld in Cumberland; mean ascospore lengths, determined from material supplied by Mr Preston and Dr Bennett to the senior writer, were $105 \pm 1{\cdot}4$ and $123 \pm 0{\cdot}8$ μ respectively. So far, the Whiteheads disease of oats has not

been reported from areas outside those in which oats are the chief cereal crop. The association of this disease with consecutive oat cropping was noted by us in Ayr, where it is the practice to take two, and occasionally three, consecutive crops of oats after ploughing up old grass. This apparent restriction of *O. graminis* var. *Avenae* to areas in which oats is the dominant cereal is somewhat difficult to explain, in view of Turner's finding that this variety of the fungus could attack wheat and barley as well as oats, though it is true that infection of these hosts in her experiments was not as vigorous as that by *O. graminis* proper. A more careful search for *O. graminis* var. *Avenae* in the south and east of England must now be undertaken; at the same time, ascospore measurements should be made on collections of wheat and barley attacked by the Take-all disease in Scotland, Wales and the north-west of England, since *O. graminis* var. *Avenae* has not yet been found on these hosts in the field, and conclusions as to their susceptibility are based solely on Turner's inoculation experiments. In this connexion, a further observation from our survey is pertinent; oats infected by *O. graminis* var. *Avenae* (mean ascospore length $112 \pm 1{\cdot}2\,\mu$) was discovered at Craibstone, Aberdeen, but wheat suffering from Take-all on another field of the same farm was found to be infected by *O. graminis* proper (mean ascospore length $71 \pm 1{\cdot}1\,\mu$).

We are much indebted to Dr David Clouston, Botanist to the North of Scotland College of Agriculture, and to Mr Laird, Agricultural Organizer for the County of Ayr, for assistance in making this survey of oat crops.

Table 1. *Ascospore measurements in* μ

Origin of sample	Mean length	Modal length	Range in length
Ochiltree, Ayr	$119 \pm 1{\cdot}8$	116	97–176
Ochiltree, Ayr	$102 \pm 1{\cdot}2$	105	84–118
Ochiltree, Ayr	$110 \pm 1{\cdot}0$	109	95–126
Ochiltree, Ayr	$107 \pm 0{\cdot}9$	109	92–123
Ochiltree, Ayr	$103 \pm 1{\cdot}1$	105	80–116
Auchinleck, Ayr	$104 \pm 1{\cdot}1$	105	84–118
Auchinleck, Ayr	$102 \pm 1{\cdot}0$	105	84–116
Tarbolton, Ayr	$109 \pm 1{\cdot}5$	105	78–126
Ayr	$101 \pm 1{\cdot}0$	105	82–116
Maybole, Ayr	$105 \pm 1{\cdot}4$	105	86–126
Dalrymple, Ayr	$105 \pm 1{\cdot}3$	105	84–126
Ceres, Fife	$105 \pm 1{\cdot}8$	105	78–134
Glenbervie, Kincardine	$108 \pm 1{\cdot}1$	105	97–126
Fetteresso, Kincardine	$106 \pm 0{\cdot}9$	105	90–122
Fetteresso, Kincardine	$108 \pm 0{\cdot}9$	105	95–120
Banchory Devenick, Kincardine	$112 \pm 1{\cdot}2$	116	90–132
Newhills, Aberdeen	$112 \pm 1{\cdot}2$	107	97–132
Kintore, Aberdeen	$114 \pm 1{\cdot}0$	115	99–126
Inverurie, Aberdeen	$102 \pm 1{\cdot}4$	101	76–116
Huntly, Aberdeen	$96 \pm 1{\cdot}3$	95	74–116
Cairnie, Aberdeen	$110 \pm 0{\cdot}8$	109	95–126

REFERENCES

DENNIS, R. W. G. & FOISTER, C. E. (1942). List of diseases of economic plants recorded in Scotland. *Trans. Brit. myc. Soc.* XXV, 266.

TURNER, ELIZABETH M. (1940). *Ophiobolus graminis* Sacc. var. *Avenae*, var.n., as the cause of Take-all or Whiteheads of oats in Wales. *Trans. Brit. myc. Soc.* XXIV, 269.

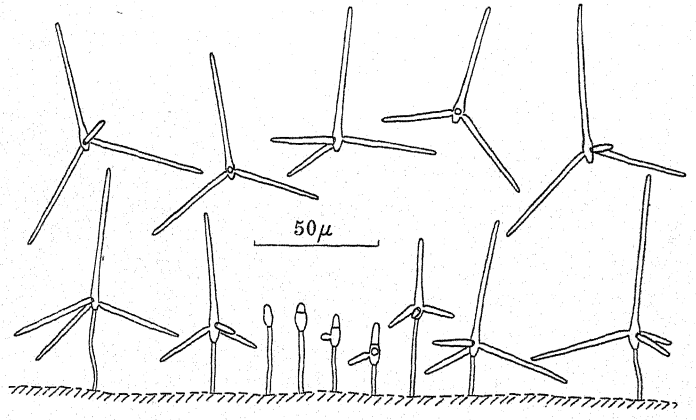
(*Accepted for publication* 14 *November* 1942)

TRISCELOPHORUS MONOSPORUS N.GEN., N.SP., AN AQUATIC HYPHOMYCETE

By C. T. INGOLD, *Department of Botany, University College, Leicester*

(With Plate VIII and 3 Text-figures)

During a brief visit to Reading in September 1942 a collection of submerged decaying leaves of various trees and shrubs was made from a rapidly flowing branch of the River Loddon at Swallowfield. Rich crops of aquatic Hyphomycetes were observed on these leaves, and, of the sixteen species discussed in a previous paper (Ingold, 1942), ten were noted. In addition, on a leaf, too rotten to be identified, the new fungus which is the subject of this paper was observed together with three other aquatic Hyphomycetes (*Clavariopsis aquatica* De Wild., *Tetracladium Marchalianum* De Wild., and *Lunulospora curvula* Ingold).



Text-fig. 1. Above: five liberated conidia. Below: nine conidiophores; the five in the middle have young spores and are arranged to show successive stages in development; the other four conidiophores bear mature spores. The substratum is shown diagrammatically. No cell contents are shown. Drawn with the aid of a camera lucida from living specimens.

The mycelium of the fungus ramifies in the tissue of the decaying leaf, and the conidiophores project at right angles into the water (Text-fig. 1 and Plate VIII, figs. 1, 6). The conidiophores are simple, 15–45 μ long, 1·5 μ wide, and the width is uniform along the entire length. Each bears a single terminal conidium of the aleuriospore type.

On the decaying leaf hundreds of conidiophores were examined with conidia at all stages of development, and from these it was easy to build up in detail a picture of conidium development (Text-fig. 1). This picture was later fully confirmed by actual observations of the course of individual conidium development using the hanging-drop method (Text-fig. 2). The

conidium starts as a small oval swelling at the end of the conidiophore. This spore primordium is soon cut off by a cross-wall. As it elongates it becomes unequally two-celled so that at this stage it looks rather like a conidium of *Venturia inaequalis*. The upper cell of the primordium continues to elongate by apical growth. Soon, from the middle of the lower cell, a small protuberance appears and grows outwards and slightly downwards as a lateral branch. When this has developed to some extent, a second lateral arises at the same level, but in a direction diverging by approximately 120° from the first branch. Later a third branch arises with the same divergence from each of the other two branches. The tip of the upper cell of the spore primordium and the tips of the three branches continue to grow until the spore is fully grown.

The mature spore thus consists of a main axis, continuous with the conidiophore, and of three divergent lateral branches forming a whorl near the base of this axis. The main axis is 50–70 μ long, 4–5 μ broad at its widest part (at a distance of 3–5 μ from its base), and it is here that the three lateral branches project, each making an angle of about 80° with the conidiophore. From its widest part the main axis tapers to 1·5 μ at its truncate base, and to 1·5 μ at its apex. The septum, which at an early stage divides the spore primordium into two cells, becomes more and more indistinct after the laterals have made their appearance, and in the mature living spore it is usually no longer visible. The lateral branches are 40–50 μ long, 2·0–2·5 μ broad near the base, but taper to 1·5 μ at the apex and are abruptly constricted to 1 μ at the attachment to the main axis.

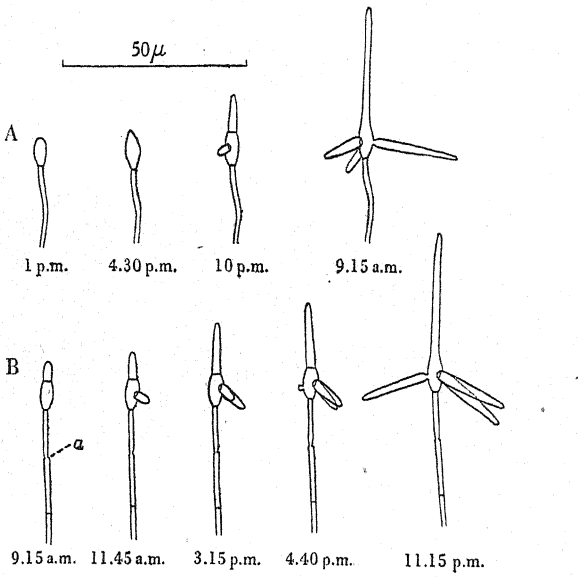
The conidium is liberated as soon as it is fully grown, by separation at the cross-wall between the spore and its conidiophore just as in *Tricladium* spp., *Tetracladium* spp., and *Clavariopsis aquatica* (Ingold, 1942).

The liberation of the spore does not necessarily end the activities of the conidiophore. Thus in the example shown in Text-fig. 2B, a conidium was produced at the point marked *a*. Then, just to the left of this scar left by the first spore, a new hypha grew out from which a new conidium developed.

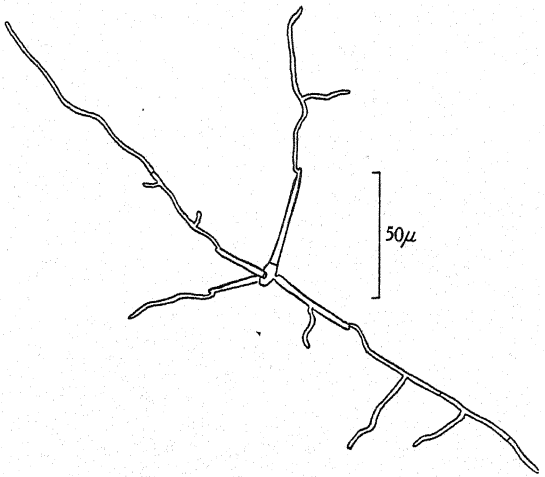
Hundreds of liberated spores have been examined. They show a great uniformity of structure. The freed spore is highly characteristic. It consists of four long divergent arms of more or less equal length. Of these one is the main axis and the other three are lateral branches. However, since the laterals are not attached at the base but only near the truncate base of the main axis, there is present on the spore a little knob, below the whorl of laterals, representing the basal part of the main axis. It is this little knob which makes the spore so characteristic. It cannot be confused with that of any of the other species of aquatic Hyphomycetes, so far described, which have spores with four long divergent arms (e.g. *Tetracladium Marchalianum*, *Articulospora tetracladia*, *Lemonniera aquatica*, *Tetrachaetum elegans*, *Heliscus longibrachiatus*, *Clavariopsis aquatica*, *Alatospora acuminata*).

The spore germinates readily in water with narrow germ tubes developing from the tips of all four arms (Text-fig. 3). Attempts to get the fungus into pure culture failed.

In comparing this species with aquatic Hyphomycetes previously



Text-fig. 2. Two examples of conidium development as observed in a hanging drop. In B the conidiophore had previously produced a conidium at the point *a*. For details see text. At 3.15 p.m. the second lateral had just begun to develop directly behind the first lateral.



Text-fig. 3. Germination of a spore in water.

described (Ingold, 1942, 1943) it is clear that the species which it resembles most, superficially, is *Lemonniera aquatica*. In most of these aquatic fungi with four-armed spores, the spore is attached to its conidiophore by the end of one of its four arms. This is so in *Tetracladium Marchalianum*, *Articulospora tetracladia*, *Alatospora acuminata*, *Heliscus longibrachiatus*, *Tetrachaetum elegans* and *Clavariopsis aquatica*. Only in *Lemonniera aquatica* and in *Triscelophorus monosporus* is the conidium attached to its conidiophore near the point of divergence of the four arms of the spore.

In *Triscelophorus monosporus* the conidiophore is unbranched. In *Lemonniera aquatica* the conidiophore is usually branched to form a terminal group of several phialides, although, not infrequently, simple conidiophores are to be seen terminated by a single phialide, and with such *Triscelophorus monosporus* shows a very marked similarity. Again in *Triscelophorus monosporus* the four arms of the spore arise in succession but in *Lemonniera aquatica* they arise simultaneously and develop simultaneously. However, the most emphatic difference, which seems to make the inclusion of the two species in the same genus impossible, is that in *Triscelophorus monosporus* the spore is an aleuriospore whilst in *Lemonniera aquatica* it is a phialospore. The importance of this distinction in aquatic Hyphomycetes has already been discussed (Ingold, 1942).

Considering aquatic Hyphomycetes which produce aleuriospores, *Triscelophorus* appears to approach most nearly to *Dendrospora erecta* (Ingold, 1943). In that fungus the conidium has a long main axis with usually two or three whorls of lateral branches arising near its base, and the lowermost of these laterals may themselves branch. In *Dendrospora erecta* the number of branches in the whorl is usually three, especially in the basal whorl. If one imagined a spore of *Dendrospora erecta* with all except the bottom whorl of branches suppressed and with no tertiary ramuli, then a spore of much the same structure as that of *Triscelophorus monosporus* would result. However, it is not suggested that the two species could be included in the genus *Dendrospora*. A new genus *Triscelophorus* (τρι, three; σκέλος, leg; φερο, to bear) is proposed, the name being suggested by the spore which consists of a main axis bearing three basal branches (legs).

Triscelophorus n.gen.

Submerged aquatic fungi with branched septate mycelium. Conidia (aleuriospores) terminal, branched, consisting of: (1) an elongated main axis continuous with the conidiophore, and (2) elongated secondary ramuli forming a whorl of three branches arising from the lower part of the main axis.

Triscelophorus gen.nov.

Fungi aquatici submersi mycelio repente septato, ramoso. Conidia (aleuriosporae) acrogena, ramosa; ramus principalis elongatus, cum conidiophoro continuus; ramuli secundarii elongati, 3-verticillati ex inferiore parte rami principalis orientes.

Triscelophorus monosporus n.sp.

Submerged aquatic fungus with branched, septate mycelium. Conidiophore hyaline, simple, straight, 15–45 μ long, 1·5 μ broad, producing a single terminal conidium. Conidia (aleuriospores) hyaline, branched, aseptate (or with a single septum in the main axis just above the point of origin of the lateral branches); main axis continuous with the conidiophore, 50–70 μ long, 4–5 μ broad (at a distance of 3–5 μ from the base) tapering to 1·5 μ at the apex and to 1·5 μ at the truncate base; secondary ramuli in a whorl of three, arising at a distance of 3–5 μ from the base of the main axis, 40–50 μ long, 2·0–2·5 μ broad near the base tapering to 1·5 μ at the apex, base abruptly constricted to 1 μ.

On a submerged decaying leaf from the River Loddon near Reading, England.

Triscelophorus monosporus sp.nov.

Fungus aquaticus submersus mycelio repente septato, ramoso. Conidiophora hyalina, simplicia, erecta, 15–45 μ longa, 1·5 μ lata, unum modo conidium acrogenum gerentia. Conidia (aleuriosporae) hyalina, ramosa, aseptata, vel rami principalis basim versus uniseptata; axis princeps cum conidiophoro continuus, 50–70 μ longus, 3–5 μ supra basim 4–5 μ latus, apicem versus ad 1·5 μ sensim attenuatus, basi truncata 1·5 μ; ramuli secundarii 3-verticillati, circa 3–5 μ supra axis principalis basim orientes, 40–50 μ longi, deorsum 2·0–2·5 μ lati, basi subito ad 1 μ constricti, sursum ad 1·5 μ sensim attenuati. *Hab.*: in folio putrescente in flumine jacente ad Reading, Anglia. *Obs.*: a *Lemonniera* De Wild. conidiorum ortus modo (aleuriospora vice phialosporae) differt.

My best thanks are due to Miss E. M. Wakefield for her assistance with the Latin diagnosis.

REFERENCES

INGOLD, C. T. (1942). Aquatic Hyphomycetes of decaying alder leaves. *Trans. Brit. myc. Soc.* XXV, 339–417.

INGOLD, C. T. (1943). Further observations on aquatic Hyphomycetes on decaying leaves. *Trans. Brit. myc. Soc.* XXVI, 93–104.

EXPLANATION OF PLATE VIII

Triscelophorus monosporus

All the photographs are from living material. The arrows indicate the junction of the conidium with the conidiophore.

Fig. 1. Conidiophore with nearly ripe conidium. The main axis of the spore and the lateral on the left are in focus, but the two laterals on the right are out of focus. × 600.

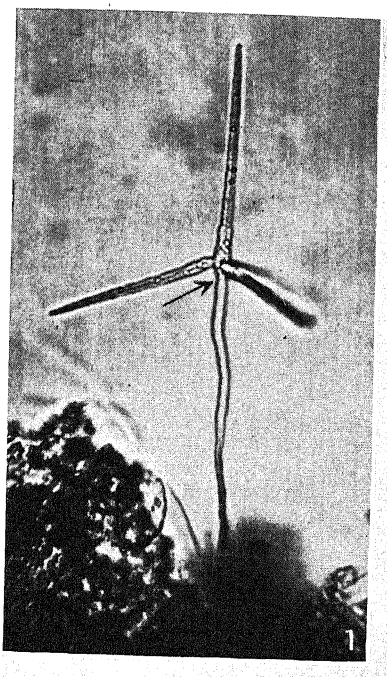
Figs. 2, 3. Spore primordium. From the lower cell of the primordium the first lateral branch of the spore is just beginning to form. Fig. 2, × 800; Fig. 3, × 760.

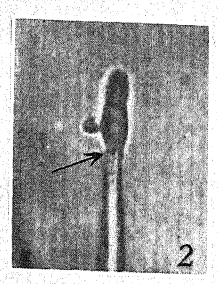
Fig. 4. Developing conidium. Two of the lateral arms of the spore have begun to develop; that on the left is in focus; the second arm is pointing directly towards the observer. × 900.

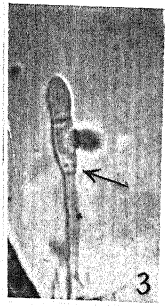
Fig. 5. Liberated spore. Note the characteristic truncate base of the main axis of the spore. × 590.

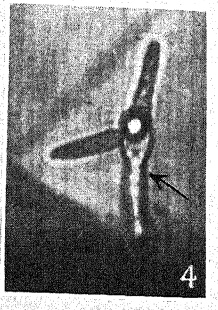
Fig. 6. Conidiophore with spore which is nearly mature. × 608.

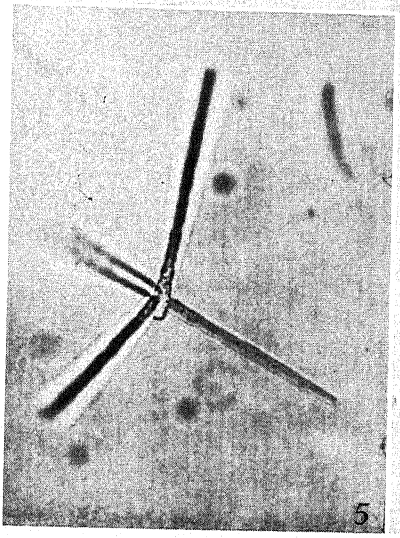
(*Accepted for publication* 11 *January*, 1943)

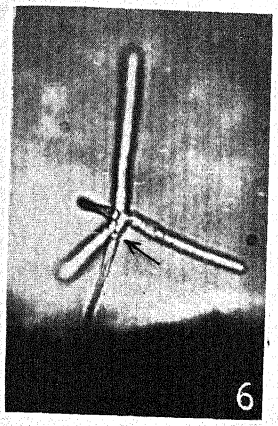

1


2


3


4


5


6

THE OCCURRENCE OF *BOTRYTIS* SPP. ON ONION LEAVES WITH SPECIAL REFERENCE TO *B. SQUAMOSA*

By C. J. HICKMAN, *Research Officer, Agricultural Research Council (now at Long Ashton Field Laboratory)*
and D. ASHWORTH, *Royal Horticultural Society's Laboratory, Wisley*

(With Plate IX and 1 Text-figure)

At the beginning of October 1941 our attention was directed to a *Botrytis* die-back of onion leaves which was damaging crops of salad and bulbing varieties sown in the summer for overwintering. Typically affected leaves (Pl. IX, fig. 1) showed a pendent, withered terminal portion of varying length, greyish green or lighter in colour, frequently studded with elliptical or circular pale spots. At the junction of the withered portion with the remaining part of the leaf the tissues were water-soaked, while below there were elliptical or circular, slightly sunken parchment-coloured spots, usually sharply delimited but sometimes with water-soaked margins. On slightly affected leaves spotting alone was apparent. Older leaves were more severely attacked than young ones.

The affected leaves bore a species of *Botrytis* with unusually large conidia. The sporulating branches of the conidiophores were much septate and gave a very characteristic corrugated appearance to the fungus especially after the conidia had fallen.

A similar disease of onions was originally recorded by Ogilvie and Mulligan (1932) where they refer to a small sclerotial *Botrytis* which proved to be highly pathogenic to onions, while in a more recent account (1941) by Ogilvie, *B. cinerea* is recorded as the causal organism. Yarwood (1938) demonstrated the association of *B. cinerea* with the disease. Comparing it with Chocolate Spot of beans he describes two types of injury, (1) oval, white or greyish sterile lesions, and (2), by the merging of similar lesions, the collapse and death of the leaves from the tip downwards.

The data collected by Ogilvie and Mulligan were kindly placed at the disposal of one of us, and they suggested that not one but two fungi were concerned. One possessed few, relatively large sclerotia and produced abundant spores measuring on malt-extract agar 9·0–14·4 × 6·5–10·1 μ, average 11·7 × 7·8 μ, characters agreeing with *B. cinerea*. The other species had many small sclerotia with a rather matted mycelium. Spores taken from a culture on leek leaf agar approximately three months old measured 14·4–22·0 × 11·2–15·5 μ, average 17·6 × 12·8 μ. Both fungi were pathogenic when inoculated into leaf incisions.

From October onwards the disease was under continual observation. Many of the leaves bore abundant conidiophores of *Botrytis*, particularly on their withered tips, while non-sporing specimens incubated overnight

in a moist atmosphere formed conidiophores profusely. A few conidiophores were observed on some of the parchment-coloured lesions. Other lesions however, remained sterile, as described by Yarwood.

The species of *Botrytis* present on affected leaves agreed in all respects with *B. squamosa*, found by Walker (1926) in America causing 'small sclerotial neck rot' of onion bulbs. This species is characterized by large conidia and by a curious 'accordion'-like degeneration of the sporulating branches of the conidiophores after the conidia have fallen—a useful diagnostic character and one which first gave a clue to the identity of the English fungus. The young conidiophores are white in mass and densely crowded. They are relatively short and stout, measuring 300–380 × 12–13 μ and become septate with maturity. With continued growth the conidiophores darken and become less compacted. After producing a crop of conidia the spore-bearing branches contract to form the characteristic accordion-like branches (Pl. IX, fig. 2). Later these fall away and the conidiophores proliferate to produce another set of branches and spores. This process may be repeated three or four times and the points at which spore-bearing branches are formed are marked in old conidiophores by slight projections (Pl. IX, fig. 3). Sometimes proliferation may also take place laterally at one of these points, thus forming a compound conidiophore.

The hyaline conidia are ovoid or, occasionally, somewhat heart-shaped and germinate by one or two germ tubes. Their relative size can be judged from Text-fig. 1, where conidia of *B. cinerea* and *B. Allii* are drawn to the same scale. The following table illustrates the close similarity in spore size of the American and English isolations.

Table 1

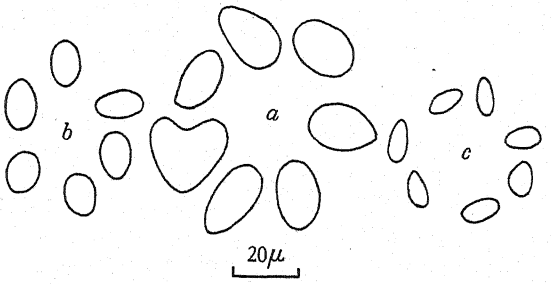
Source of culture	Range μ	Majority μ	Average μ	Medium
Walker	13–24 by 9–18	15–22 by 11–15	—	?
Hampton 1	16–25 by 9–20	19–22 by 13–16	20·9 by 14·7	Host
	13–24 by 9–16	16–20 by 12	18·5 by 12·6	*P.D. agar
Hampton 2	13–28 by 12–19	19–22 by 13–16	20·1 by 14·7	Host
	12–22 by 8–16	16–20 by 12–14	17·8 by 12·6	P.D. agar
Bretforton 1	14–24 by 11–19	19–22 by 13–16	19·4 by 15·2	Host
	12–26 by 10–18	16–22 by 10–12	19·1 by 11·7	P.D. agar
Bretforton 2	8–25 by 8–16	13–22 by 13	17·6 by 12·5	Host
	12–24 by 10–16	20 by 12–14	19·2 by 12·6	P.D. agar
Bretforton 3	12–26 by 12–18	16–20 by 12–14	19·5 by 13·4	Host
Pebworth	12–28 by 12–16	20–24 by 12–14	21·9 by 13·7	Host
	12–24 by 10–16	16–20 by 12–14	18·4 by 12·6	P.D. agar
Badsey 1	12–24 by 10–16	16–20 by 12–14	18·5 by 13·0	Host
Badsey 2	12–28 by 12–20	16–22 by 14–16	19·2 by 15·4	Host
Perdiswell	8–26 by 8–16	16–22 by 12–14	19·1 by 12·6	Host
Wisley	16–26 by 14–22	18–24 by 16–20	22·0 by 17·0	Host
			17·2 by 13·2	P.D. agar

* Potato-dextrose agar.

In a collection which was left in a moist chamber for several weeks, small black sclerotia, up to 5 mm. across, were observed on the leaves

which by this time were completely rotten and disorganized. Sclerotia were not found on diseased leaves in the field.

The fungus grows well on potato-dextrose agar, producing in slant cultures a white surface felt of mycelium which later becomes somewhat



Text-fig. 1. Showing the relative shape and size of conidia of *a*, *B. squamosa*; *b*, *B. cinerea*; *c*, *B. Allii*.

wavy, and, after three to four weeks at laboratory temperature, numerous black sclerotia 1–5 mm. across, often coalescing at the side of the culture. Conidia are rarely developed until cultures are about three months old, the conidiophores being borne almost exclusively on the surface of the sclerotia. In general, conidia produced in culture are slightly smaller than those on the host.

Recalling the description of the unidentified small sclerotial *Botrytis* isolated by Ogilvie and Mulligan, it will be observed that it agrees with *B. squamosa*—matted mycelium, numerous small sclerotia and large spore size. Further, the fact that spore measurements were taken from an old culture suggests the tardy conidial development of *B. squamosa*. It is therefore probable that this fungus was isolated as early as 1931 in this country.

In addition to *B. squamosa*, isolations corresponding to *B. cinerea* and of a third, at present unidentified, *Botrytis* were obtained from diseased onion foliage, suggesting that the disease is not associated with a single specific organism. In these investigations however, *B. squamosa* was the predominant fungus. It was recorded on ten occasions, from widely separated localities, while *B. cinerea* appeared only twice, once in association with *B. squamosa*.

As no healthy controls were available, no data could be gathered on the ultimate effect of the disease. In the spring, affected plants grew away from the disease apparently unharmed. The only exception was a variety imported from Egypt—Chandawil Bright—which was very susceptible both to *Botrytis* and to winter weather. The foliage was first almost totally destroyed in early October by *Botrytis*, and the destruction of the plants was completed by winter frosts. Apart from this variety, no marked varietal differences in susceptibility were observed, the popular White Lisbon salad onion and various bottoming varieties being equally affected.

No experiments were carried out to test the pathogenicity of the fungi isolated under controlled conditions. With the exception of Ogilvie's un-

published record that *B. cinerea* and what we conclude to be *B. squamosa* were pathogenic when agar-bearing mycelium was placed on wounded leaves, no information on this point exists in this country. According to an abstract in the *Review of Applied Mycology* of a paper by Van Poeteren (1939), *B. squamosa* was isolated from the dead leaves of potted onion plants but its connexion with the decay could not be determined. In America however, Walker (1926) tested the pathogenicity of this fungus towards onion foliage by spraying leaves with a spore suspension. After finding that leaves were not attacked unless plants were left in a moist chamber for a week or more (at 18° C.), he remarks that 'in an extremely humid environment having a favourable temperature, infection of the aerial parts by *B. squamosa* may occur', but that 'there is little evidence that this form causes a destructive leaf blight'. He presents no evidence of leaf infection by this fungus in the field during the growing season of the bulb onion crop. Similarly, *Botrytis* infection did not appear here on onion foliage during the summer months, its development being limited to the autumn and winter period. One further point of significance regarding the etiology of this disease is that *Botrytis* infection was sometimes associated with mild attack by Downy Mildew (*Peronospora Schleideniana*). The conidiophores of the latter fungus were sparsely distributed amongst the dense masses of *Botrytis* fructifications. It seems probable that we are dealing here with an example of facultative parasitism, infection being governed either by increased susceptibility of the host during autumn and winter as a result of adverse weather conditions, Downy Mildew attack and/or by the favourable effect of the relatively moist conditions, on the development of *Botrytis*.

The occurrence of *B. squamosa* is of some importance because it may cause a neck rot of onion bulbs (Walker, 1926). It does not seem to be virulently parasitic however, for when pieces of an agar culture of the fungus were laid on the necks of onion bulbs in a moist chamber no rotting followed. We have not found it naturally occurring on onion bulbs but this may only reflect its rarity as an agent of onion neck rot, for Walker himself found it to be less common than the other neck-rot organisms *B. Allii* and *B. byssoidea*.

SUMMARY

A die-back disease of onion foliage characterized by pale spotting and death of the leaves from the tip downwards, associated with *Botrytis* infection, was investigated during 1941–2. Of three species of *Botrytis* isolated from diseased leaves, *B. squamosa*, recorded for the first time in this country, was the predominant organism. The other fungi were *B. cinerea* and an unidentified form. Infection was limited to autumn and winter and plants usually grew away healthy in spring and summer. The disease is probably an example of facultative parasitism.

We wish to express our gratitude to Mr L. Ogilvie for permission to include certain data and to Dr C. G. C. Chesters for assistance in taking photographs. Our acknowledgments are also due to Long Ashton Research Station for Pl. IX, fig. 1.

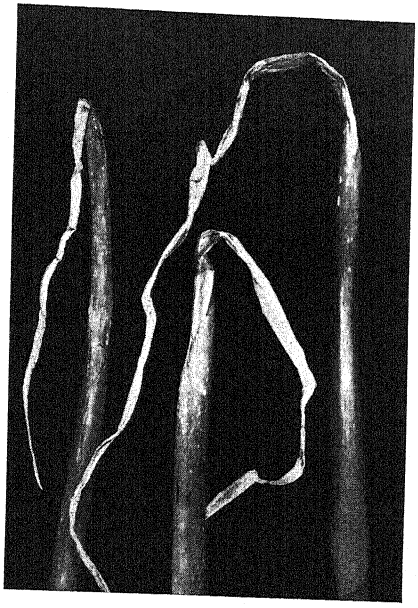


Fig. 1

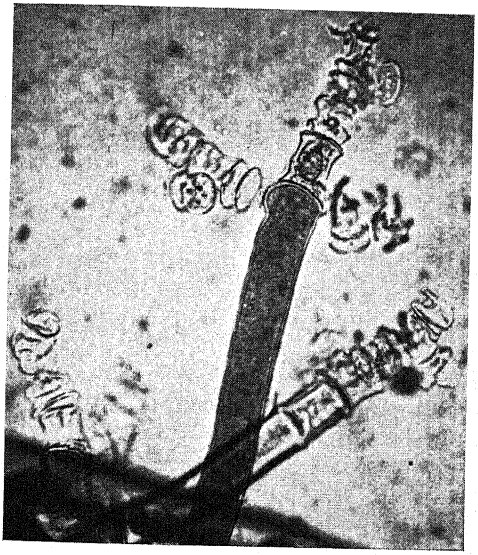


Fig. 2

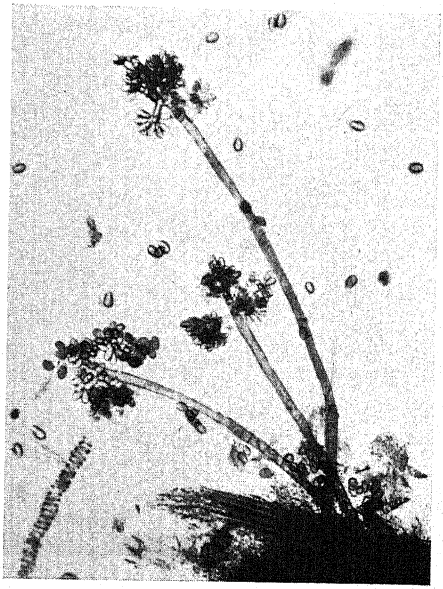
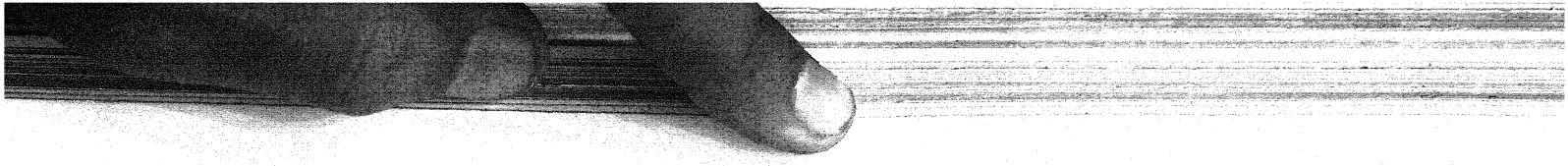


Fig. 3



REFERENCES

OGILVIE, L. & MULLIGAN, B. O. (1932). Progress report on vegetable diseases. III. *Ann. Rept. Agric. Hort. Res. Sta., Long Ashton, Bristol, for* 1931, pp. 119–32.
OGILVIE, L. (1941). Diseases of Vegetables. *Bull. Minist. Agric. London,* no. 123, p. 29.
VAN POETEREN, N. (1939). Onderzoek over het koprot in de Uien van de oogst 1938. *Versl. PlZiekt. Dienst Wageningen,* p. 90. Cited in *Rev. appl. Myc.* XIX, 188–9.
WALKER, J. C. (1926). *Botrytis* neck rots of onions. *J. Agric. Res.* XXXIII, 893–928.
YARWOOD, C. E. (1938). *Botrytis* infection of onion leaves and seed stalks. *Plant Dis. Rept.* XXII, 428–9.

EXPLANATION OF PLATE IX

Fig. 1. White Lisbon Onion leaves affected by *Botrytis* die-back. Approx. half natural size.
Fig. 2. Conidiophores of *B. squamosa* showing the 'accordion' degeneration of the spore-bearing branches after the conidia have fallen. ×600.
Fig. 3. Old conidiophores of *B. squamosa* showing the points of attachment of former spore-bearing branches. ×85.

(*Accepted for publication* 24 *February* 1943)

OBSERVATIONS ON THE GENUS *MYROTHECIUM* TODE

I. THE THREE CLASSIC SPECIES

By N. C. PRESTON

(With Plates X and XI and 7 Text-figures)

Introduction

My attention was drawn to this genus when a *Myrothecium* tentatively referred to *M. roridum* Tode was found to be an active parasite of cultivated violas (Preston, 1934). It was also recorded as parasitic on *Antirrhinum majus* by Taubenhaus (1934) in U.S.A. and in 1939 it was found at Cambridge on the same host by Brooks who sent it to me. An attempt to establish the identity of the fungus in *Viola* led to a general study of the genus and primarily to an examination of the three classic species considered here.

Historical

The genus *Myrothecium*, now classified in the Tuberculariaceae, was founded by Tode (1790) and was adopted in an emended form by Fries (*Systema Mycologicum* 1829) with four species, three of which he distinguished according to the nature of the disk and the shape of the spores thus:

M. roridum Tode: disk swollen, spores cylindric.

M. verrucaria (Alb. & Schwein.) Ditmar: disk flattened, spores ovate.

M. inundatum Tode: disk flat, spores globose.

The fourth species, *M. scybalorum* (Schum.) Fr., is otherwise only known from Schumacher's (1803) description and figure as *Peziza scybalorum*.

A search of the available *exsiccata* showed that the three classical species recognized by Fries can be clearly distinguished, though certain modifications of the original diagnoses must be made. During this study two of these species, *M. roridum* and *M. verrucaria*, have also been recognized in living material obtained from widely separated localities, and cultures of them have been maintained and studied.

The original diagnosis for the genus (Tode, 1790) was: '*Fungus cyathiformis*; *cupula superni volvata*; *repletura seminali lentoviscida*', i.e. Fungus cup-shaped; cups surrounded by a sheath; when filled with spores slowly sticky. Tode described five species: *M. roridum*, *M. inundatum*, and three others which were later stated by Fries to belong to quite other genera. He did not describe or figure the spores. The habitat of *M. roridum* was given as the damp remains of oak and pine branches; that of *M. inundatum* as a dried up agaric. Tode's genus was emended by Link (1809) who based his description on *M. inundatum* Tode and stated that Tode's other species

were very different. His diagnosis was as follows: '*Sporangium figurae indeterminatae. Peridium simplex laxe floccosum tandem in medio evanescens. Sporidia minutissima globosa, prima aetate fluidiuscula, dein compacta*', i.e. Sporangium irregular in shape. Peridium simple, loosely woolly, at length disappearing at the centre. Spores very small, globose, at first somewhat fluid, then compact. Meanwhile, Albertini and Schweinitz (1805) had described a fungus said to be frequently found on very rotten cucumber leaves in Germany. This they named *Peziza verrucaria*, although they recognized its resemblance to the *Myrothecia* of Tode as the disk of the receptacle was at first adhesively sticky and then hardened; they did not describe its spores.

Ditmar (1813) described and figured *M. inundatum*, repeating Link's statement that the spores were globose. He also collected a fungus with oval spores on *Lapsana communis* and identified it with *Peziza verrucaria* A. & S. which he transferred as *Myrothecium verrucaria* (A. & S.) Ditmar. It was Tode's genus as emended by Link and Ditmar which Fries (1829) accepted. The characteristic feature of the genus, which evidently impressed Tode and is specifically referred to by both Schumacher (1803) and Link (1809), is the semi-liquid or viscid nature of the spore mass when fresh. Three other points in Link's and Ditmar's emendation require particular attention. First, Link included only a single species, *M. inundatum*, in his emended genus; second, both Link (1809) and Ditmar (1813) described its spores as globose; and third, the reference to a woolly (*laxe floccosum*) margin to the disk.

Myrothecium was first recorded for Britain by Greville (1825) when he described *M. Carmichaelii* occurring on 'masses of subputrescent vegetable substances' in Appin. He stated that this species was readily distinguishable from both *M. inundatum* and *M. verrucaria* in its cylindrical spores. Fries (1829) identified Greville's new species with *M. roridum* Tode, which was thus reinstated in the genus.

No more exact information about these three species became available until Saccardo (1880) identified *M. roridum* and *M. verrucaria*, and, in 1881, figured and described them and *M. inundatum*. His descriptions are as follows: '*M. roridum sporodochia plana, atra, albo-marginata, conidia, cylindrica, utrinque obtusa* 8–10 × 2 μ (raro 14 × 2 μ), 2 *guttulata, dilute olivacea, basidiis filiformibus* 30 × 2 μ *suffulta*' and '*M. verrucaria* differt in *conidiis oblongo-ovatis* 9 × 3 μ, 2 *guttulatis, olivaceis, basidiis filiformibus sesquilongioribus suffultis*', i.e. *M. roridum* sporodochia flat, black, white fringed, conidia cylindrical with blunt ends 8–10 × 2 μ (rarely 14 × 2 μ), biguttulate, pale olivaceous, supported on filiform basidia 30 × 2 μ, and *M. verrucaria* differs in (having) conidia oblong-ovate 9 × 3 μ, biguttulate, olivaceous supported on filiform basidia about half as long again as the spores. His figure of *M. inundatum* shows that he regarded the spores of this species as semi-globular, measuring 3–4 × 1·5 μ.

Höhnel (1905) pronounced the spores of *M. inundatum* to be oblong rod-shaped, 3–4 × 1–1·5 μ, and not globose. He also stated that he found long white setae in young specimens of this species though they were generally absent from the mature margin of the sporodochium.

The type species

As we have seen, only one of Fries's three clearly defined species, *M. inundatum*, was actually included by Link and Ditmar in their emended genus which Fries accepted. As this species alone has remained in the genus since its inception it is proposed as its natural type. Link no doubt identified the species from its peculiar habitat, viz. dried agarics, and, since it is

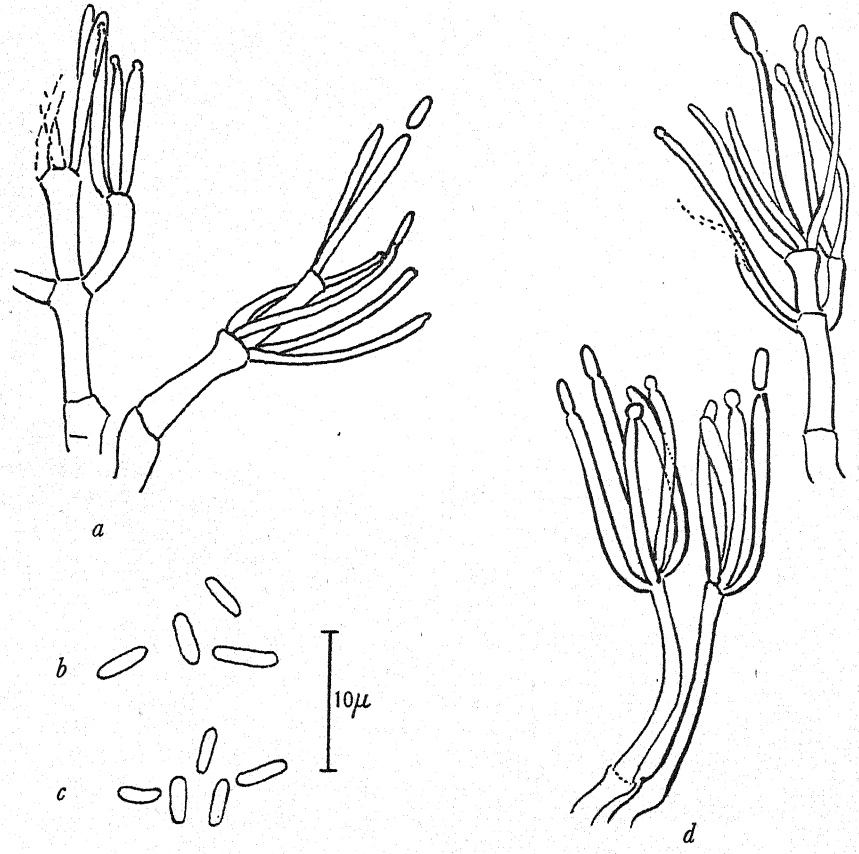


Fig. 1. *Myrothecium inundatum* Tode. *a*, conidiophores and phialides ex Carmichael Herb. Hort. Edinb. (freehand drawing). Spores: *b*, ex Carmichael Herb. Kew; *c*, ex Herb. Petch (on *Russula adusta*). *d*, ex Ellis and Everhart Herb. Kew (freehand drawing). *a*, ×2000 approx.; *b*, *c*, ×1800; *d*, ×2000 approx.

almost certain that no type specimen now exists, it seems legitimate to assume that the published exsiccata of *M. inundatum*, all of which are on similar substrata, do indeed represent the same species as that originally described by Tode. This being so, it is evident that Link's description of the spores as globose is incorrect. All the specimens examined bear out Höhnel's statement that they are rod-like, 3–4 × 1–1·5 μ (Text-fig. 1), but

since short rods may easily appear to be spherical, especially under a low magnification, Link's error is readily understandable. The presence of long white setae, figured by Nees (1817) and described by Höhnel, has also been confirmed. Though these could not be found in the Kew exsiccata they were easily recognizable in most of the fructifications of more recently collected material which Mr T. Petch generously provided from his own herbarium (Pl. X).

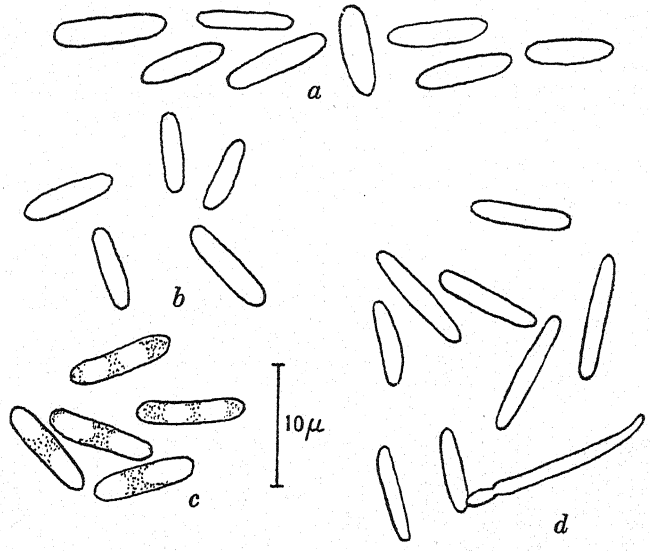


Fig. 2. *Myrothecium roridum* Tode ex Fr. Spores. *a*, ex Antirrhinum; *b*, ex *Viola*; *c*, ex *Lycopersicum*; and *d*, *M. Carmichaelii* Grev. ex Type specimen Herb. Hort. Edinb.

The other classic species

The original diagnosis (Greville, 1825) for *M. Carmichaelii* Grev. is: '*Peridio polymorpho candido; sporulis viridibus nigrescentibus cylindricis*', i.e. peridium irregular in form, white; with sporules green becoming black, cylindrical. The type specimen of *M. Carmichaelii* Grev., still preserved in the Edinburgh Herbarium, has been examined. Its fructifications conform to Tode's original description of *M. roridum*. Fries regarded *M. Carmichaelii* Grev. as synonymous with *M. roridum* Tode. Following Fries, therefore, we can make use of the type of *M. Carmichaelii* for the recognition of *M. roridum* Tode as accepted since the time of Fries. The parasite on *Viola* can thus be identified as *M. roridum* Tode in the accepted sense, and a number of similar fungi received from the Imperial Mycological Institute can also be referred to this species; these will be dealt with later.

The third species accepted by Fries, *M. verrucaria* (Alb. & Schwein.) Ditm., is readily distinguishable by the shape of the spores, described as ovate (Fries), or oblong-ovate (Saccardo). Whether the type specimen of *Peziza verrucaria* A. & S. still exists is doubtful, and, as it has apparently

never been re-examined, we have no means of verifying the shape of its spores. The three published exsiccata issued as *M. verrucaria* A. & S., in the Kew Herbarium, all have distinctly oval spores quite different in shape from, and somewhat darker in colour than those of *M. roridum*. Their dimensions are slightly smaller than those given by Saccardo, but in shape they conform to his figure (Pl. III). When highly magnified, the spores of all three specimens show a distinct flattening, or even a minute protuberance, at the broader (basal) end and they are therefore correctly described as truncate. Three living specimens of a similar fungus obtained in cultures from the Imperial Mycological Institute have spores corresponding closely both in shape and size with those of the Kew exsiccata of *M. verrucaria* and they are therefore referred to this species (Text-fig. 3*a*, *b*).

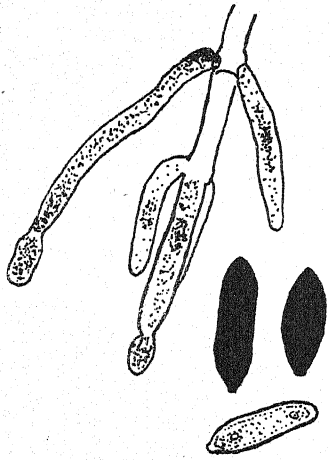


Fig. 3*a*. *Myrothecium verrucaria* Tode ex Fr. ex Citrus fruits (Bates) (freehand drawing).

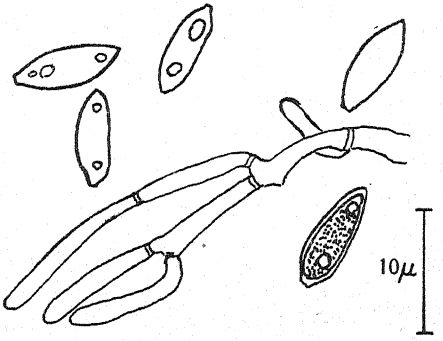


Fig. 3*b*. *Myrothecium verrucaria* Tode ex Fr. ex Potato (Cyprus) Nattrass.

While it has been found possible to distinguish the three species of *Myrothecium*, viz. *M. inundatum*, *M. roridum* and *M. verrucaria*, by means of spore shape and size, it is very doubtful whether Fries's other criterion for their separation, the shape of the disk, is tenable as a specific character. If by the term 'disk' Fries meant the shape of the spore-mass, this of course varies with the age and consequent dryness of the fructifications. In young viscid fructifications of both the *roridum* and the *verrucaria* types, the spore-mass is generally rounded or conical, but after drying it tends to become flat. The dried specimens of *M. inundatum* which have been examined have flat or even slightly concave spore-masses, but the spores of this species are undoubtedly cylindrical though much smaller than those of what we may call the *roridum* type. Supposing, alternatively, that when describing the 'disk' Fries is referring to the hymenial surface formed by the closely aggregated phialides directly below the spore-mass itself, this still provides no distinguishing character corresponding with the shape of the spores. In both cylindrical-spored or truncate-spored forms this disk may be either flat, umbonate (swollen) or even undulating.

THE LIVING MATERIAL

(1) *Myrothecium roridum*. Living British material (Text-figs. 2, 4 and 5) of this species has been obtained from three different host plants all of which are cultivated species, viz. *Viola tricolor*, *Antirrhinum majus* and *Lycopersicum esculentum*. I have not collected it upon any wild species of *Viola* or other plants nor upon plant debris. It occurs quite frequently upon garden violas, and isolates have been obtained from a number of different varieties of these. The isolate from *Antirrhinum* was kindly supplied by Prof. Brooks from Cambridge, and this was also found to grow readily upon detached but unsterilized *Viola* stems. The material from tomato was isolated from a sporodochium occurring upon a greenhouse plant, the

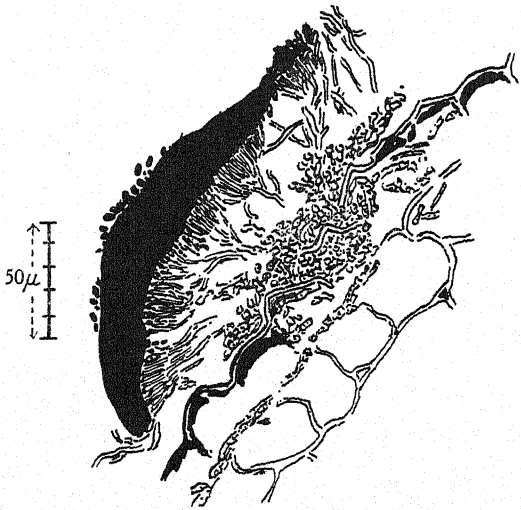


Fig. 4. *Myrothecium roridum* Tode ex Fr. Section through sporodochium on *Viola* (natural infection).

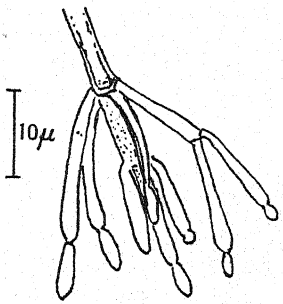


Fig. 5. *Myrothecium roridum* Tode ex Fr. ex *Antirrhinum majus*.

stem of which had been attacked also by *Botrytis cinerea*. Inoculation of this isolate on to young living tomato plants produced only very slight superficial lesions and no sporodochia were formed.

The isolates obtained from these three plants have been grown upon a variety of artificial media such as cherry, malt extract, corn-meal and potato-dextrose agars and they produce sporodochia upon all of them. On corn-meal agar mycelial development is slight and the fungus from *Viola* usually stains this medium bright yellow. Apart from this colour reaction, the isolates are indistinguishable from one another both in their macroscopic appearance and in the shape and dimensions of their spores (Text-fig. 2). They closely resemble the exsiccata of *M. roridum* Tode, including the type specimen of *M. Carmichaelii* Grev., though their spores are somewhat shorter and broader, on the average, than those of the herbarium specimens. The spore and phialid measurements are compared in Table 1.

In addition to the British material just described several cultures of *Myrothecium* from the Imperial Mycological Institute have been critically examined. Among these, the following, all collected by Deighton in Sierra Leone, are considered referable to *Myrothecium roridum* Tode ex Fr.:

No. 937, ex *Hibiscus esculentus*.
No. 880, ex *Dolichos Lablab*.
No. C. B. 881 A, also ex *Dolichos Lablab*. (Text-fig. 6).
No. 849 A, ex *Trichosanthes*.
An unnumbered specimen, ex *Asclepias* sp.

Table 1. *Spore measurements of* Myrothecium roridum *Tode ex Fr. from various sources*

Source	Spores: Range μ	Spores: Average μ
Exsiccata:		
M. Carmichaelii Grev., Appin Type, Herb. Hort. Edin.	8–10 × 1–2	9·5 × 1·3
M. roridum Tode, H. W. R(avenal) Herb. Kew, North America	8–12 × 2–2·5	9·0 × 2·0
Isolates:		
ex *Viola*, England	5·5–8·0 × 1·5–2·5	6·6 × 1·9
ex *Antirrhinum*, England	6·0–9·0 × 1·5–2·5	7·1 × 1·9
ex *Lycopersicum*, England	6·0–10·0 × 1·5–2·5	8·3 × 2·0
ex *Hibiscus*, West Africa	6·5–10·5 × 1·5–2·5	9·4 × 2·0
ex *Dolichos*, West Africa	6·0–11·0 × 2·0–3·0	8·3 × 2·6
ex *Trichosanthes*, West Africa	5·5–9·0 × 2·0	7·4 × 2·0
ex *Asclepias*, West Africa	6·0–8·0 × 1·0–2·0	6·9 × 1·7

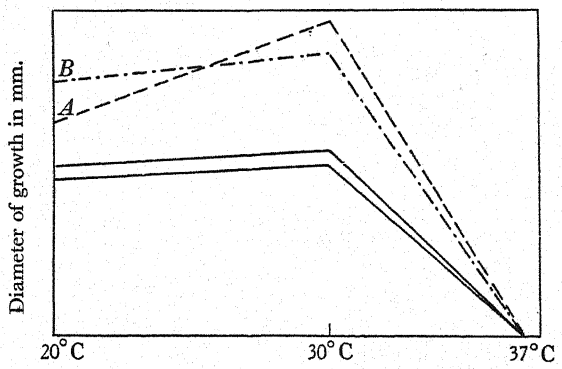


Fig. 6. Extent of growth of *M. roridum* at different temperatures after 4 days. Continuous lines = British isolates, both from *Viola*; broken lines = West African isolates. *A*, from *Asclepias*; *B*, from *Dolichos Lablab*.

Of these three fungi Nos. 937 and 880 reacted as very active parasites when inoculated on to living *Viola* stems, producing typical lesions upon which sporodochia developed after a few days. The fungus No. 849 A, ex *Trichosanthes*, differs somewhat from the others in producing, on agar, a coarse mycelium which tends to form into thick strands, but its sporodochia and spores are typical. This fungus either failed to infect, or produced only very slight lesions, when inoculated on to living *Violas*.

Temperature and pH relations. In spite of the difference in their habitat both the British and African specimens of *M. roridum* showed a very similar response to temperature in their rate of growth. The optimum temperature for each is about 30° C., but all grow almost equally well at 20° C., the African forms making slightly more rapid growth than the British ones at either of these temperatures (Text-fig. 6). Growth was inhibited in all at a temperature of 37° C.; the African forms, however, remained viable after four days at this temperature and resumed growth when transferred to a temperature of 23° C., whilst the British forms made no recovery under similar conditions (Text-fig. 6).

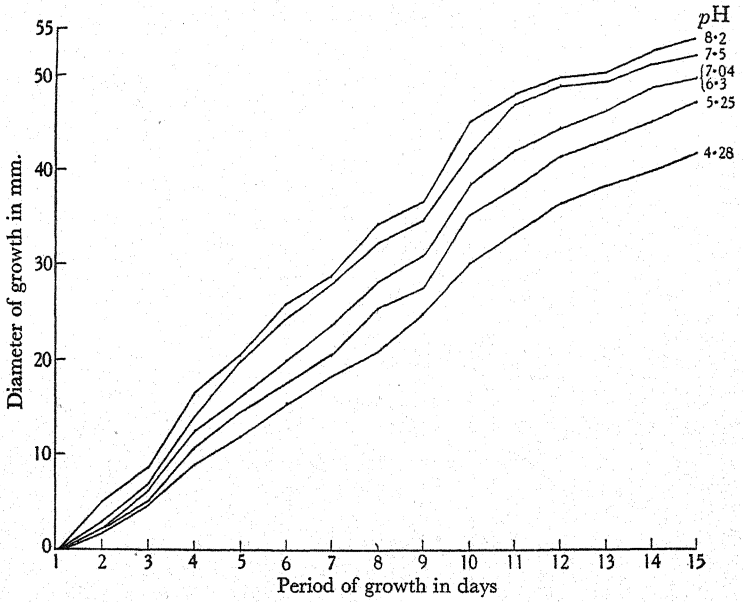


Fig. 7. Effect of *p*H of medium on rate of growth of *Myrothecium roridum*, isolated from *Viola*. Each reading = average of three Petri-dish cultures. Medium: 2·5% malt extract agar adjusted for *p*H. [The curves for *p*H values 7·04 and 6·3 became identical after 7 days and closely approximated one another up to this date; a mean reading is therefore given for these over the first 7 days.]

The effect of the *p*H of the medium has been investigated only for the British isolates from *Viola*. These were grown on 2·5% malt extract adjusted in range from *p*H 3·4 to 8·2. No growth occurred on the very acid medium, but the fungus grew normally at *p*H 4·8 and the rate of growth increased slightly with rise of *p*H from this point to the maximum of 8·2. Alkalinity of the medium was definitely favourable to growth as will be seen by reference to the graph (Text-fig. 7). The figures for each *p*H are the average of the extent of growth measured on three plate cultures. The plates were inoculated by puncturing the agar at the centre with a platinum wire previously dipped in a suspension of the requisite spores in sterile water.

(2) *Myrothecium verrucaria.* This species is easily distinguishable from

M. roridum by its elliptical, ovoid or lemon-shaped spores though the sporodochia are very similar. It appears to be unrecorded in Britain.

Three living cultures, referred to *M. verrucaria* A. & S., after comparison with the published exsiccata of the species, were obtained from the Imperial Mycological Institute. These are:

No. 162. Collected by G. R. Bates from the washings of citrus fruits in Southern Rhodesia.

No. 878. Collected by R. M. Nattrass from potato foliage in Cyprus.

A culture (unnumbered) isolated from soil in the Sudan by T. W. Clouston.

Nattrass's fungus is evidently a parasitic form. It was originally obtained from living potato haulms and has been found to grow quite readily on detached but living pieces of potato haulm and also upon living cucumber leaves on moist filter paper in large deep Petri dishes. This is of interest since Albertini and Schweinitz described their *M. verrucaria* as being frequently found upon subputrescent cucumber leaves and it seems that this species, like *M. roridum*, has formerly been regarded only as a saprophyte.

Temperature relations. The optimum temperature for growth of the isolates from potato and citrus is about 30° C. but, unlike *M. roridum*, *M. verrucaria* can tolerate a temperature of 37° C. though at this temperature its growth is retarded and tends to become abnormal and wrinkled.

All three isolates grow and fructify readily upon the same artificial media as were used for the culture of *M. roridum*.

(3) *Other species of* Myrothecium. Two other species received from the Imperial Mycological Institute will be described more fully in another paper. One of these, No. 145, collected by Jollyman in Nyassaland on drying tobacco leaves, is possibly identical with *M. gramineum* Lib. It has rod-like spores similar to those of *M. roridum*, but its rather large sporodochia are provided with long pointed setae.

The other fungus, isolated by Neil from a clay soil in New Zealand, appears to be a new species. It is distinguished by having distinctly striate spores.

The following are emended descriptions of the genus *Myrothecium* and of its three classic species.

Myrothecium Tode ex Fr.

Sporodochia shallow cups, with or without a pseudoparenchymatous base, covered with a viscid spore-mass at first green, becoming jet black, with a white margin of flocculent contorted hyphae, with or without setae. *Conidiophores* septate, hyaline or olivaceous, consisting of a main axis which is once or twice branched, and crowned with a whorl of closely appressed phialides. *Phialides* slenderly clavate, hyaline or pale olive green. *Conidia* small, cylindrical, or elliptical with a truncate base; continuous, subhyaline or pale olive green, abstricted singly to form a black viscid mass.

Myrothecium inundatum Tode ex Fr.

Sporodochia small 0·3 to about 1·5 mm. in diameter, about 0·05 mm. deep, circular or irregular in surface view, often confluent, black with pure white floccose margin and numerous evanescent setae. *Setae* arising more or less horizontally from below the sporodochium and bending sharply upwards at its margin, hyaline, thick-walled, septate, tapering with blunt apices, usually three to five celled, 100 to at least 300 μ long, 3–4 μ wide in region of basal septum, slightly narrower below and tapering to 2 μ at apex. *Conidiophores* erect, irregularly branched, hyaline; main axis tapering, three to four celled, cells slightly broadening below their distal septa; branches one to two celled arising immediately below a septum of the parent axis, closely intertwined. *Phialides* very slenderly clavate, hyaline, 9–22 μ long, 1–2 μ broad, arising in groups usually of from three to seven from the apices of the main axis and its branches or borne laterally, either singly or in small whorls, just below a septum of the parent branch; forming a compact hymenium-like layer. *Spores* very small, continuous, cylindrical with rounded ends, 3–4 $\mu \times$ 1–2 μ, sub-hyaline or greenish, aggregated when dry into a firm flat or slightly concave mass.

Myrothecium roridum Tode ex Fr.

Sporodochia sessile, discoid, circular or irregular in surface view, 0·1 to about 1·5 mm. in diameter, about 0·05–0·1 mm. deep, often confluent into larger masses; green at first, becoming black, white rimmed, without setae, arising either directly from the mycelium or from a pseudoparenchymatous stroma erupting from the epidermal cells of the host and composed of the intertwining conidiophores. Margin woolly consisting of loosely intertwined unicellular contorted hyphae with blunt ends arising from below the conidiophores and tending to curve inwards. *Conidiophores* erect, once or twice branched, septate, hyaline, main axis tapering, three to four celled, cells broadening slightly below their distal septa, basal cell about 30 $\times$ 3 μ, apical cell about 10 $\times$ 1·5 μ; branches one or two celled, arising singly or in pairs or whorls either directly from the terminal cell of the parent axis or immediately below the septum of an intermediate cell, each branch terminating in a whorl of phialides. *Phialides* slenderly clavate, straight, hyaline, usually arranged in whorls of three to seven at the apices of the main axis and its branches but sometimes arising singly or in small whorls immediately below a distal septum of an intermediate cell, 10–12 $\times$ 1–2 μ, forming a closely packed hymenium-like layer. *Conidia* cylindrical or very slightly tapering with rounded ends, continuous, two to three guttulate, hyaline at first, becoming pale green, 5–9 $\times$ 1–2·5 μ (average 8 $\times$ 2 μ). Spore-mass green, becoming jet black, viscid, globular or conical at first, finally dry, dull black, flattened or slightly concave.

Myrothecium verrucaria (Alb. & Schwein.) Ditmar ex Fr.

Sporodochia, conidiophores and phialides essentially similar to those of *Myrothecium roridum*. *Conidia* elliptical with a truncate base, smooth, continuous, two to three guttulate, subhyaline to pale olive green 6–10 $\times$ 2–4·5 μ. Spore-

mass green, becoming jet black, viscid, globular or conical at first, becoming dry, dull black and flattened.

I gratefully acknowledge the loan of the type specimen of *Myrothecium Carmichaelii* and other material from the Edinburgh Herbarium and the facilities afforded me at the Royal Herbarium, Kew, and the Imperial Mycological Institute. My thanks are also due to Dr C. G. Chesters for the reproduction of the plate from *Grevillea*, to Mr T. Petch and Prof. F. T. Brooks for material which they provided, and especially to Mr E. W. Mason for invaluable criticism and help throughout, particularly in connexion with the historical survey and the reproduction of plates.

Note. After the paper was written, Mr G. Smith (London School of Tropical Medicine) furnished me with what seems to be the first British record of *Myrothecium verrucaria*. The fungus was found by Dr Turfitt on an old canvas shoe (possibly of American origin) in Sherwood Forest.

REFERENCES

ALBERTINI, J. B. & SCHWEINITZ, L. D. (1805). *Conspectus fungorum in Lusatiae superioris agro Niskensi crescentium*, p. 340, tab. 8, fig. 6.
DITMAR, L. P. F. (1813). Pilze in Sturm, J., *Deutschlands Flora*, III, taf. 4.
FRIES, E. M. (1829). *Systema Mycologicum*, III, 1, 216–18.
GREVILLE, R. K. (1825). *Scottish Cryptogamic Flora*, III, tab. 140.
HÖHNEL, F. v. (1905). Über *Myrothecium* und fernverwandte Gattungen. *Annal. Myc.* III, 559–60.
LINK, H. F. (1809). Observationes in Ordines plantarum naturales. *Diss. I. Magaz. d. Ges. naturf. Freunde Berlin*, III, 1, 23.
NEES, E. C. G. v. (1817). *Das System der Pilze und Schwämme*, p. 104, tab. 8, fig. 98.
PRESTON, N. C. (1934). The parasitism of *Myrothecium roridum* Tode. *Trans. Brit. Myc. Soc.* XX, 242–51.
SACCARDO, P. A. (1880). *Michelia*, II, 175.
SACCARDO, P. A. (1881). *Fungi italici autographice delineati*, tab. 858–60.
SCHUMACHER, C. F. (1803). *Enumeratio plantarum in partibus Saellandiae septentrionales et orientales*, II, 418. Cited from Fries, E. M., *Systema Mycologicum*, 218.
TAUBENHAUS, J. J. (1934). On a black crown rot of greenhouse snapdragons caused by *Myrothecium roridum* Tode. *Phytopath.* XXV, 969.
TODE, H. J. (1790). *Fungi Mecklenburgensis selecti*, I, 25.

EXPLANATION OF PLATES X AND XI

PLATE X

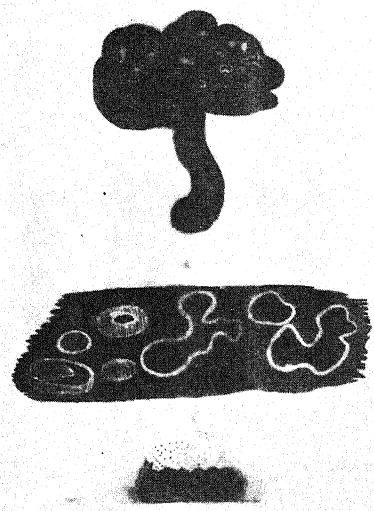
Fig. 1. *Myrothecium inundatum* after Ditmar (1813).
Fig. 2. *Myrothecium inundatum* after Saccardo (1881).
Fig. 3. *Myrothecium inundatum* (on *Russula adusta*) ex Herb. Petch. Sporodochium; spore-mass removed to expose setae, × 100.
Fig. 4. *Myrothecium inundatum* (on *Russula adusta*) ex Herb. Petch. Spores, × 1000.

PLATE XI

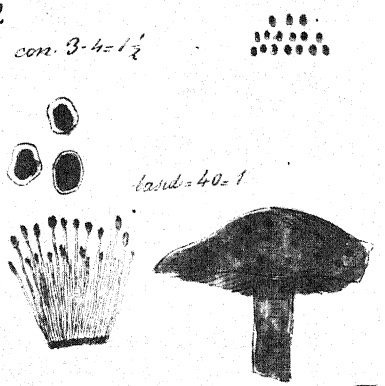
Fig. 5. *Myrothecium roridum* after Saccardo (1881).
Fig. 6. *Myrothecium verrucaria* after Saccardo (1881).
Fig. 7. *Myrothecium Carmichaelii* after Greville (1825).
Fig. 8. *Myrothecium Carmichaelii* ex Herb. Hort. Edin. Phialides and spores, × 1000.
Fig. 9. *Myrothecium roridum* on *Viola*. Two sporodochia viewed from above, × 50 approx.

(*Accepted for publication* 20 *February* 1943)

1



2

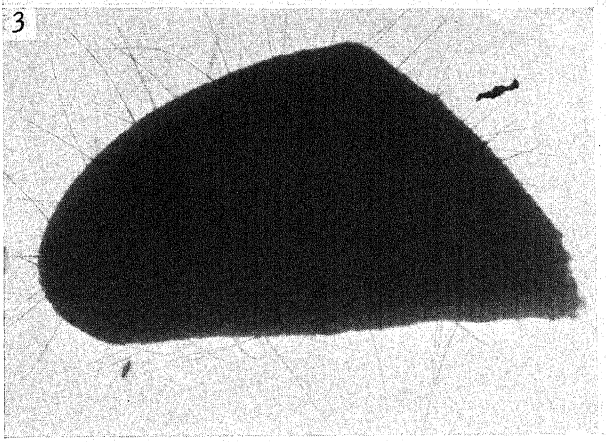


con. 3-4=1½

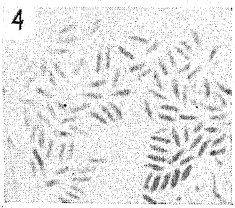
basid.=40=1

Myrothecium mandatum Tode
Mich. I 478
Belluno, in fungis Carlinae
nec putridis.
Oct. 1879

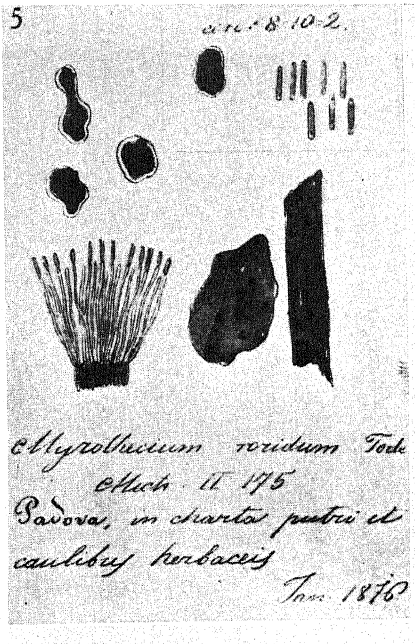
3



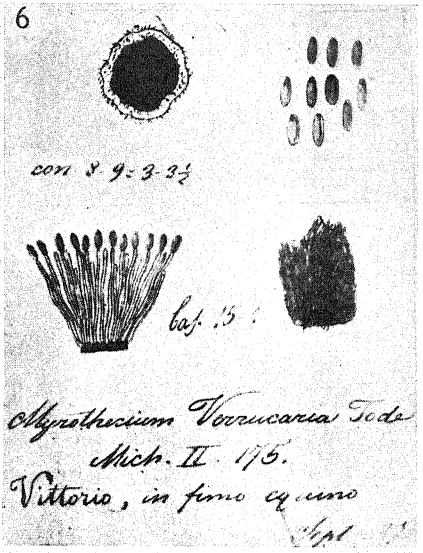
4



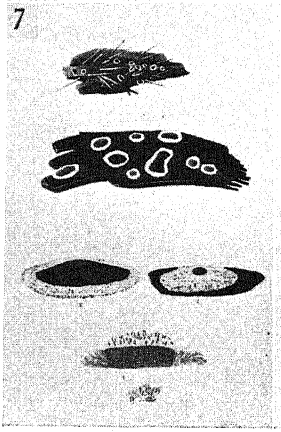
5


Chlyrothecium roridum Tode
Mich. II 175
Padova, in charta putri et
caulibus herbaceis
Inv. 1876

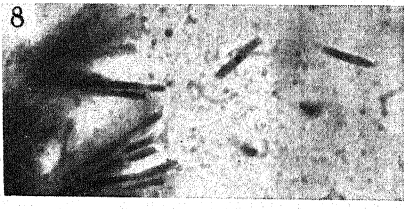
6


Myrothecium Verrucaria Tode
Mich. II 175.
Vittorio, in fimo equino

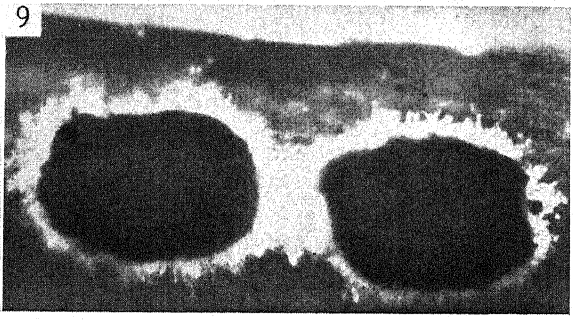
7



8



9



STUDIES IN THE GENUS *USTULINA* WITH SPECIAL REFERENCE TO PARASITISM

VI. A BRIEF ACCOUNT OF HEART ROT OF BEECH (*FAGUS SYLVATICA* L.) CAUSED BY *USTULINA*

By W. H. WILKINS, *Mycology Laboratory, University Department of Botany, Oxford*

(With Plate XII)

When starting the investigation into the pathogenicity of *Ustulina* in 1933, the intention was to show that beech is subject to a serious heart rot caused by this fungus. This work was delayed by inability to secure adequate evidence because material for detailed examination was not available. In the meantime, however, it has been shown that *Ustulina* causes a heart rot of lime (Wilkins, 1936) and of elm (Wilkins, 1939). In both trees no fungus other than *Ustulina* could be isolated from the diseased timber, so this was obviously the pathogen. Several beech trees have been examined during the past six years, and though no old tree has been found in which *Ustulina* was the only fungus present, it seems probable that it is often the primary and major cause of decay, for in younger trees, where decay is less advanced, no other causal organism has been isolated.

Recently, a beech tree which showed typical *Ustulina* heart rot was felled in the Botanic Gardens, Oxford. Though, owing to the author's preoccupation with medical research, this tree was not investigated in detail, it seems desirable briefly to put this and other cases of *Ustulina* heart rot of beech on record.

The tree was a fine specimen, about 170 years old with no external symptoms of disease. When cut across about 2 ft. 6 in. above ground level, the greater part of the centre of the trunk was seen to be decayed in the manner characteristic of *Ustulina* (Pl. XII, fig. 3). Isolations from the decayed timber showed that though certain other (unidentified) fungi were present, the greater part of the wood was diseased by *Ustulina* as most of the isolations gave pure cultures of that fungus. This tree was situated about twenty yards from the site of the lime tree previously recorded by me (1936) as being diseased by *Ustulina*. This might imply infection via lateral roots, but though the roots of the lime were to some extent decayed, this decay did not extend to the extremities, and, moreover, the lateral roots of the beech were quite sound. The centre of the root was completely rotten, and it seems probable that the heart-rot infection was due to die-back and consequent decay of the tap-root system as described by Day (1934). *Ustulina* may be a wound parasite, but in all the cases of heart rot of beech examined by me, and in most other heart rots caused by this fungus, infection was invariably via the decayed tap root. The decay extended up the trunk to a height of 12 ft., rendering the timber economically useless.

The symptoms of decay in this tree are almost identical with those found in beech trees examined at Blenheim Park, Woodstock (Pl. XII,

fig. 1), Arundel Park, Sussex (Pl. XII, fig. 2) and elsewhere, all of which were decayed by *Ustulina*. Macroscopic examination of a transverse section across a diseased trunk indicates the major symptoms of decay as follows:

(1) The centre of the trunk is more or less occupied by a patchily discoloured area with a very irregular outline which bears no relation to the distribution of annual rings (Pl. XII, figs. 1–3).

(2) This area may be bounded by a definite black line as shown on the left side of the section illustrated in Pl. XII, fig. 2. If this line is not present when the tree is freshly cut, it may develop as the timber dries out.

(3) If a transverse slice of the trunk be put in the dark and kept moist, the surface will probably become covered with the dark, felty, white-edged mycelium of *Ustulina* (Wilkins, 1936, Pl. XII, fig. 3).

(4) Certain isolated patches of the timber in the discoloured area are distinguished as being darker, softer and distinctly more wet than the rest. These patches usually indicate the presence of another species of fungus. Such patches are well shown in Pl. XII, figs. 1, 3.

(5) Whether a peripheral black line is evident or not, the most characteristic feature of the disease is the presence of black lines irregularly distributed throughout the decayed wood (Pl. XII, figs. 1, 4). These have a general tendency to run radially but with numerous interconnexions and irregularities. They may occasionally be double. Black lines may be produced by certain other fungi but those of *Ustulina* are very characteristic and slight experience enables them to be used as a diagnostic feature. An example of the general arrangement of the black lines in a dried-out block of timber is shown in Pl. XII, fig. 4. A photograph of a trunk of beech showing typical symptoms of *Ustulina* heart rot, with peripheral black line well emphasised in certain parts, is shown by Cartwright and Findlay (1942) Pl. V, fig. c.

It is hoped that microscopic examination of the fungus timber relationship may be done later.

REFERENCES

CARTWRIGHT, K. ST G. & FINDLAY, W. P. K. (1942). Principal decays of British hardwoods. *Ann. appl. Biol.* XXIX, 219–53.

DAY, W. R. (1934). Development of disease in living trees. *Wood preserv. Assoc. J.* IV, 25–44.

WILKINS, W. H. (1936). Studies in the genus *Ustulina* with special reference to parasitism. II. A disease of the common lime (*Tilia vulgaris* Hayne) caused by *Ustulina*. *Trans. Brit. Myc. Soc.* XX, 133–57.

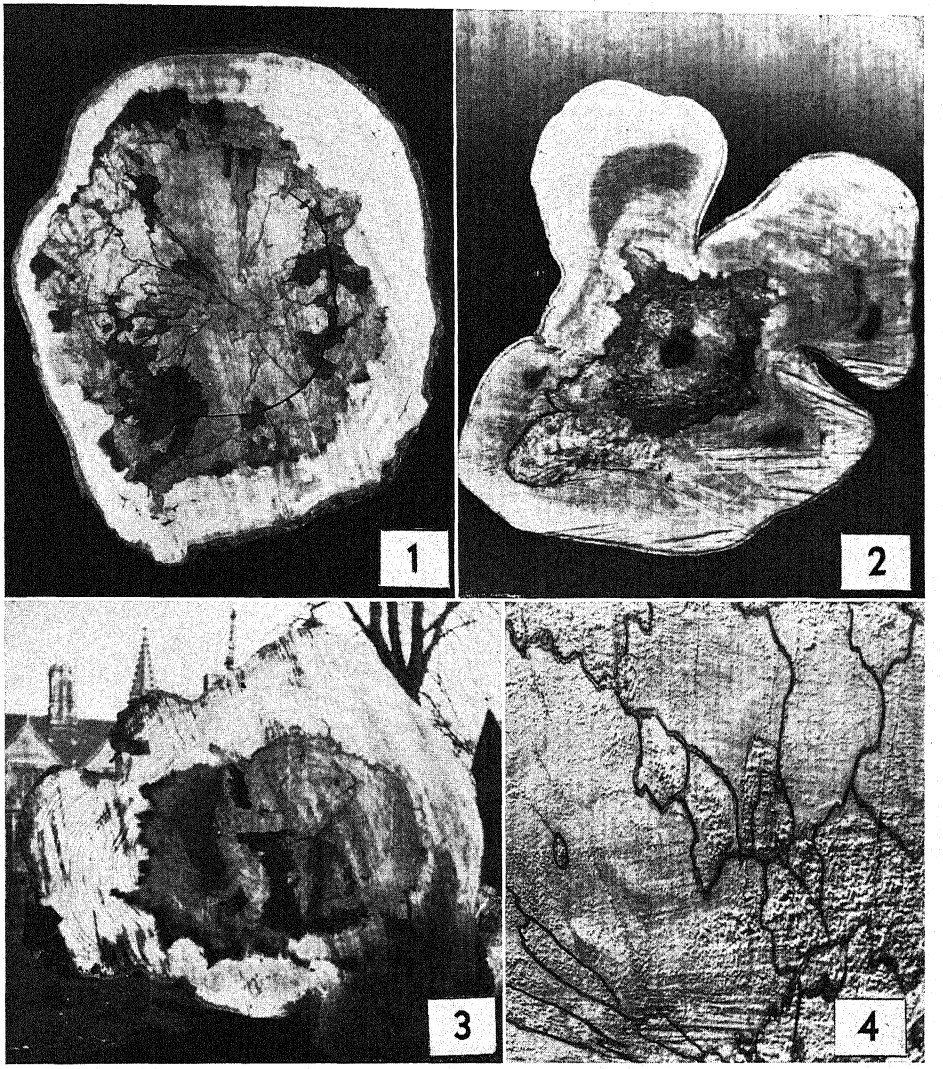
WILKINS, W. H. (1939). Studies in the genus *Ustulina* with special reference to parasitism. V. A disease of elm (*Ulmus campestris* Sm.) caused by *Ustulina*. *Trans. Brit. Myc. Soc.* XXIII, 171–85.

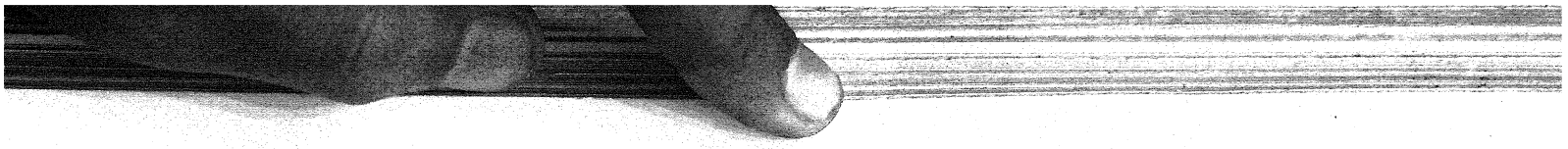
EXPLANATION OF PLATE XII

Transverse sections across beech trunks decayed by *Ustulina* heart rot.

Fig. 1. An advanced stage of decay in tree from Blenheim Park, Woodstock.
Fig. 2. A young beech from Arundel Park, Sussex, with actively growing *Ustulina*.
Fig. 3. Tree from Botanic Gardens, Oxford, with a stage of decay intermediate between the above two.
Fig. 4. Transverse section of dried-out timber from fig. 1 enlarged to show black line.

(*Accepted for publication* 18 *April* 1943)


1
2
3
4



INTERNATIONAL ASSOCIATION OF MICROBIOLOGISTS NOMENCLATURE COMMITTEE

Appointment of Judicial Commission on Bacteriological Nomenclature

At the Third International Congress for Microbiology held in New York City in September 1939, a series of recommendations of the Permanent International Committee on Bacteriological Nomenclature were accepted at the Plenary Session of the Congress. The third and fourth recommendations were:

> That the Nomenclature Committee, as at present constituted, shall continue to function under the auspices of the International Association of Microbiologists as it did under the International Society for Microbiology.*

> That the International Committee shall select from its membership a Judicial Commission consisting of twelve members, exclusive of members *ex officio*, and shall designate a Chairman from the membership of the Commission. The two Permanent Secretaries of the International Committee on Bacteriological Nomenclature shall be members *ex officio* of the Judicial Commission. The Commissioners shall serve in three classes of four commissioners each for nine years, so that one class of four commissioners shall retire at every International Congress. In case of the resignation or death of any commissioner, his place shall be filled for the unexpired term by the International Committee at its next meeting.

By prompt action at and subsequent to the Congress ballots were cast in spite of war conditions by 26 of the 62 members of the Permanent Committee on Nomenclature. These ballots when examined by the undersigned Joint Secretaries of the Permanent Committee in November 1942 were found to have resulted in the election of the persons whose names appear below. These are grouped in the three classes specified by the Permanent Committee, those receiving the highest number of votes being placed in the nine-year class, those receiving the next highest in the six-year class, etc. Names in the classes are arranged alphabetically.

Elected for nine years (term normally expires in 1948): R. E. Buchanan (U.S.A.), A. J. Kluyver (The Netherlands), E. G. D. Murray (Canada), S. Orla Jensen (Denmark). *Elected for six years* (term normally expires in 1945): J. Howard Brown (U.S.A.), A. R. Prévot (France), J. Ramsbottom (Great Britain), Th. Thjötta (Norway). *Elected for three years* (term normally expired in 1942): A. Lwoff (France), E. Renaux (Belgium), A. Sordelli (Argentine), C. Stapp (Germany).

It has been decided to make this arrangement in the hope that some plan for taking tentative action on questions of nomenclature can be developed by those members of the Commission who can be reached under war conditions.

While no provision was made in 1939 for the contingencies that have arisen, it is felt that those elected should serve until successors are elected. Prof. R. E. Buchanan has been asked to act as Chairman *pro tem.* of the Judicial Commission, as there is no possibility of securing an election under the rules as adopted.

ROBERT S. BREED (*Geneva, New York*)
R. ST JOHN-BROOKS (*London*)
Joint Permanent Secretaries, International Committee on Bacteriological Nomenclature

* The International Society for Microbiology was replaced in 1936 by the International Association of Microbiologists, which was formed by plenary resolution at the Second International Congress for Microbiology, London, 1936.

Note by Dr R. St John-Brooks, Lister Institute, Elstree, Herts

The functions of the Judicial Commission were defined by recommendations which were adopted by the Third International Congress for Microbiology, New York, 1939, in Plenary Session (see *Report of Proceedings*, p. 35). Any questions respecting interpretation of rules or recommendations in nomenclature may be submitted in the prescribed manner to the Chairman, but bacteriologists in Great Britain and the British Empire may find it convenient to refer their problems in this field in the first instance to Dr St John-Brooks, who will then take further necessary action.

It is hoped that the Judicial Commission will, among other matters, now be in a position to consider the proposed Bacteriological Code of Nomenclature which, under the aegis of the Nomenclature Committee, has been further developed by Prof. Buchanan and his collaborators since the last Congress for final disposition at the Fourth International Congress for Microbiology, whenever that may take place.

(*Accepted for publication* 14 *March* 1943)

THE MEASUREMENT OF PLANT DISEASES IN THE FIELD

In 1941 the Society's Plant Pathology Committee began an attempt to evolve practical and reliable standard methods of recording disease quantitatively in the field, and a first progress report on the scheme has already been published (*Trans. Brit. Myc. Soc.* XXVI, 1943, 28). Further experience was gained in 1942, when about 800 estimates of disease were received. The diseases concerned were potato Blight, potato-virus diseases, sugar-beet Virus Yellows, Take-all, Eyespot and Loose Smut of wheat, and apple Scab.

Various methods of estimating the extent of virus disease in potato and sugar-beet crops and of fungus diseases in cereal crops have now been adequately tested, and the Committee is satisfied that the following methods for use in survey and other work with these crops can be recommended as reliable and essentially practical. The method suggested for virus diseases of potato and sugar beet should be capable of application to most diseases of this nature. Further work is necessary before standard methods of measuring potato Blight and apple Scab can be recommended.

Virus diseases of potato and sugar beet. Where 1 % of disease or less is present in a crop it is usually sufficient to estimate the amount by visual examination according to Table 1.

Table 1

% of disease	Potato	Sugar beet
0	Not seen on field	Not seen on field
0–0·1	1 affected plant in 12 yd. radius	1 affected plant in 7 yd. radius
0·1–1·0	1 affected plant in 4 yd. radius	1 affected plant in 2 yd. radius

If more than 1 % is estimated in this way counts should be made by taking *random* samples on each of two diagonal traverses of the field. The number of plants to be counted depends on the accuracy needed. For general survey purposes five random samples of from 50 to 100 plants each would be adequate, whereas for special purposes, such as certification of crops, at least twice this number of samples would be desirable. The actual method of counting can be left to the individual observer, so long as it is done consistently from the random sampling position.

Cereal crops. Cereal Smuts, and Take-all (*Ophiobolus graminis* Sacc.), Eyespot (*Cercosporella herpotrichoides* Fron) and Brown Foot Rot (*Fusarium* spp.) of cereals as far as they have caused Whiteheads, can all be recorded from the same traverses of the field. Low percentages of disease can be estimated visually according to Table 2.

Table 2

% of disease	Limits
0–0·01	Less than 1 affected head in 50 sq. yd.
0·01–1·0	Less than 2 affected heads in 1 sq. yd.
Above 1·0	More than 2 affected heads in 1 sq. yd.

If more than 1 % is estimated, counts should be made by taking ten grab samples *at random* on a zigzag or diagonal traverse of the crop. Each sample should contain not less than 20 eared tillers. To ensure random sampling a grab may be made with both hands extended and eyes closed. The stem bases of the 200 or more eared tillers thus collected which shew Whiteheads should be examined and separated into three groups according as they are attacked by *Ophiobolus*, *Cercosporella* or *Fusarium*. The percentage number of tillers substantially attacked by the different organisms can then be calculated. The amount of Smut present can be determined from the numbers of ears affected. Smut may also be estimated by counts of suitable samples when the crops are in stook.

(*Accepted for publication* 4 *April* 1943)

PROCEEDINGS

Meeting held in the rooms of the Linnean Society of London, 13 February 1943.

The President, Dr S. P. Wiltshire, M.A., in the Chair.

N. C. Preston. Some observations on the genus *Myrothecium*.

Professor A. Fleming and G. Smith. Some methods of mounting and preserving mould cultures.

H. A. Dade. Application and uses of Fleming's mounting methods.

Miss B. J. Legge. On *Phytophthora* crown rot of *Campanula* with reference to soil-borne infection.

S. Dickinson. Experiments on the physiology of obligate parasitism. 4. The growth of rust mycelium from out of infected leaves.

C. T. Ingold. Two aquatic Hyphomycetes.

Meeting held in the rooms of the Linnean Society of London, 16 April 1943.

The President, Dr S. P. Wiltshire, M.A., in the Chair.

Reports from the Society's Committees

Plant Pathology Committee. Secretary: J. H. Western.

G. R. Bisby. The list of common British plant diseases.

W. Buddin. Plant disease measurement.

Nomenclature Committee. Secretary: Miss E. M. Wakefield.

Edible Fungi Sub-Committee. Convenor: J. Ramsbottom.

Foray Committee. Secretary: Mrs E. W. Mason.

REVIEWS

Aquatic Phycomycetes exclusive of the Saprolegniaceae and Pythium. By FREDERICK K. SPARROW Jr. Pp. xix + 785, frontispiece and 69 text-figures. (University of Michigan Studies, Scientific Series, 15.) University of Michigan Press and Oxford University Press, 1943. $5.

Dr Sparrow's *Aquatic Phycomycetes* will have a warm welcome from the members of the British Mycological Society, many of whom know the author. Those who were at the Haslemere Foray in 1932 (*Trans. Brit. Myc. Soc.* XVIII, 1933, 7) will recall the surprising collection of aquatic fungi that Dr Sparrow made from the small pond behind the Haslemere Educational Museum, and more will remember the talks he gave at our meetings.

The scope of the book has been limited deliberately to those Phycomycetes which live in water, except for those specially mentioned in the title. Some genera of lower fungi, such as *Synchytrium* and *Physoderma*, are omitted; and some groups, notably the Plasmodiophorales, are described only in part. The omissions are not disadvantageous, for the adoption of a biological criterion to fix the limits of the book has enabled the author to obtain a unity which could hardly have been got in any other way.

Within the boundaries he has set, Dr Sparrow presents an enormous mass of detail, impossible to analyse in a short review. Much of this detail is drawn from his own observations, for he has travelled widely in Europe and America, and has seen in the living state very many of the fungi he describes. To his great practical experience of the organisms he has joined a thorough and critical study of the work of his forerunners. This union gives to us a masterly and comprehensive account of the Phycomycetes found in water, and the account may be regarded as practically complete to the date of publication of the book.

No doubt because he has worked and thought so much, Dr Sparrow takes up a conservative position. He knows well that there remain many gaps in our knowledge and that those gaps can be filled only by more observations. He does not hide his own views, but he states them without dogmatism; there is a very pleasant absence from the book of pontification and of special pleading designed to support some pet theory. The author is clearly much more interested in his subject than he is in himself, and he very successfully preserves the objective attitude so desirable in botanical writings.

All students of aquatic life, whatever their special interests, will find *Aquatic Phycomycetes* of very great help. The book sets out plainly what is known, and describes methods by the use of which more may be learned. We may well hope that when the present troubles are over, Dr Sparrow's book will promote an intensive investigation of aquatic fungi, for now those who desire to study those organisms have a reliable guide to point the way.

The University of Michigan is to be congratulated on the addition of another valuable book to their scientific publications. If the reviewer may be allowed one grumble, it might have been better if so large a book had been issued in two volumes. B. BARNES

A Dictionary of the Fungi. By G. C. AINSWORTH and G. R. BISBY. Pp. viii + 359, 138 figs. Imperial Mycological Institute, Kew, 1943. 20*s*.

A dictionary of the fungi in English and of convenient size has long been desirable. Drs Ainsworth and Bisby have now produced a useful and welcome volume which is considered to include a list of generic names of the fungi complete to the end of 1939; supplementary material has already been printed in the *Review of Applied Mycology*.

The book is an alphabetic arrangement of the names of genera and groups of higher rank, with the names of the more important plant diseases, many technical terms, some sixty-four longer sections dealing briefly with most of the general matters that interest mycologists, and ten short biographical notices of outstanding mycologists of the past. The lichens are described in a general section, but the genera are not listed; a few bacterial genera are listed. Prof. G. W. Martin has allowed his well-known scheme of classification to be printed as an appendix. The illustrations are grouped at the end, where they are easily found.

The more a reader browses in the book the more it becomes clear that it is a useful tool. The numerous references to original sources show where additional information may be sought, so that the dictionary is a guide to the books as well as to the fungi. The working mycologist cannot be without this dictionary, and the undergraduate will find it of service to him. No doubt, the specialist will find fault here and there. Perhaps he will send on his comments to the authors, for this Dictionary should go into subsequent editions, and necessary changes can then be made. The book deserves well of British

INDEX

New names are indicated by an asterisk

PRINTED IN GREAT BRITAIN BY
W. LEWIS, M.A., AT THE
UNIVERSITY PRESS, CAMBRIDGE